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Application of a Hazard Assessment Research Strategy to the Ocean Disposal of a Dredged Material: Exposure Assessment Component

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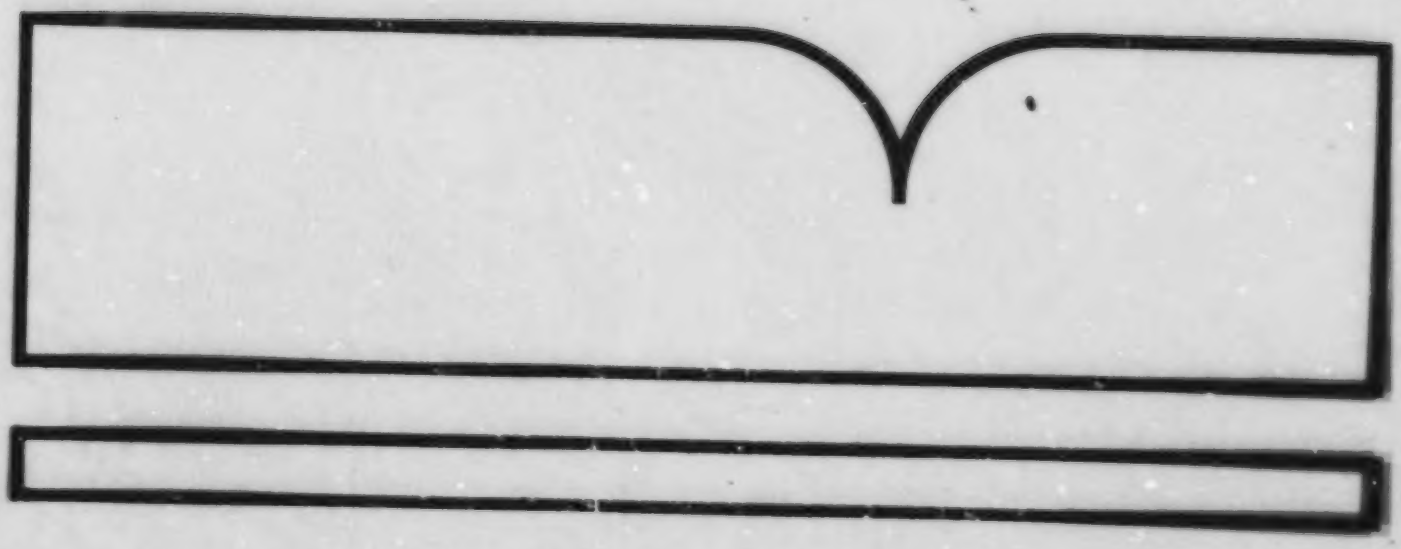

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THE APPLICATION OF A HAZARD ASSESSMENT RESEARCH STRATEGY TO THE OCEAN DISPOSAL OF A DREDGED MATERIAL: EXPOSURE ASSESSMENT COMPONENT

by

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ABSTRACT

The exposure assessment component of the aquatic portion of the Field Verification Program (FVP) relates the source input of the dredged material contaminants to the corresponding concentration distributions in space and time in the vicinity of the disposal mound. The specific objectives for this component are: (1) determine the environmental exposure field at the biological effects measurement stations in the water column (pelagic zone), in the sediments (benthic zone), and at the near-bottom/sediment-water interface (epibenthic zone); (2) relate the source (dredge disposal mound) to the near-field exposure measurements using process models for the vertical transport of contaminants and particulate materials; and (3) determine the environmental processes controlling contaminant phase partitioning.

Approximately 55,000 cubic meters of material were disposed during May 1983. This created a mound approximately 200 meters in radius in water of 20 meters depth. The central part of the disposal mound was composed of sand-size particles mixed with silty material, while the flanks and fringes of the mound were composed entirely of extremely fine-grained material. For the first few months after the disposal operation, the dominant sediment resuspension mechanism at the site was the tidally-generated currents. There were no major storms during this period.

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The water column chemical measurements indicated that there was a dredged material contaminant signal (three times background) in the vicinity of the disposal mound for about a month after the disposal operation. After this period of time, the water column exposures approached background levels. The tissue residues for caged mussels, deployed one meter above the bottom, gave similar results: elevated levels for the first month after disposal followed by a return to background levels. The contaminant signal in the sediments was more persistent. It was also measureable (two to three times background) at a kilometer from the disposal mound three months after disposal. Moreover, polychaete tissue residues were elevated (two to three times background) at a kilometer from the disposal mound three months after disposal. The exposure assessment information that has been obtained will be used in the laboratory-to-field link phase of the FVP.

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1. INTRODUCTION

The U. S. Army Corps of Engineers and the U. S. Environmental Protection Agency (EPA) are jointly conducting a comprehensive study, referred to as the Field Verification Program (FVP), to evaluate the risks associated with various disposal options for dredged materials (Dillon, 1984). The approach being used in the FVP is to evaluate and field validate assessment methodologies for predicting the environmental impacts of dredged material disposal in aquatic, upland, and wetland environments. The EPA Environmental Research Laboratory-Narragansett (ERLN) is conducting the aquatic portion of this program.

The ERLN research plan for the aquatic portion of the FVP is an application of the hazard assessment research strategy that has been developed at ERLN for ocean disposal (Bierman et al., 1984; Gentile et al., 1984; and Gentile and Pesch, Chapter 00). The basic objective of this strategy is the development of quantitative relationships between source inputs of wastes contaminants and their transport, transformation, fate, and effects in the aquatic environment. Hazard assessment consists of two basic components: exposure assessment and effects assessment. Exposure assessment provides the causal link between source inputs and environmental concentration distributions, while effects assessment provides the causal link between exposure concentrations and biological effects. The synthesis of

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outputs from these two components provides a unified framework for assessing the response of an environmental system to the disposal of a particular waste material.

Exposure assessment involves the collection and synthesis of information on source inputs with information on the physical, chemical, and biological processes which affect the transport, transformation, and fate of waste contaminants in the environmental system. Mathematical models provide a useful quantitative framework for this synthesis. Such models can describe the physical processes affecting contaminant movement in the system, such as convection and dispersion in the water column, and mass fluxes between the water column and bedded sediments. They can also describe chemical and biological processes affecting the transformations and distributions of the contaminant in the water column, sediment, and biota. These processes could include adsorption/desorption, degradation, and biological uptake.

This paper describes the exposure assessment component of the aquatic portion of the FVP, its specific objectives, and the data acquisition and synthesis necessary to meet the overall objectives of the FVP (Gentile and Pesch, Chapter 00). Results are presented to describe the conditions at the disposal site for the predisposal period and for the first full season after the disposal operation.

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2. EXPOSURE ASSESSMENT PLAN FOR THE FVP

Since EPA is a regulatory agency, research at ERLN must relate to specific needs in support of the ocean disposal regulatory process (Fig. 1). The endpoint is the potential ecological impacts which may result from contaminant exposures. Environmental exposure is the linkage between the input of the material into the environment and the subsequent biological effects.

One of the main thrusts of the FVP is the field validation of laboratory assessment methods for predicting the environmental impacts of dredged material disposal (Gentile and Pesch, Chapter 00). Laboratory tests have been conducted with both suspended and solid phase material from Black Rock Harbor (BRH), the source of the dredged material, in flow-through, constant exposure laboratory systems (Johns et al., Chapter 00). Further laboratory tests will be conducted simulating the actual field exposure conditions observed at the center of the disposal mound, on the fringes of the mound, and at locations away from the mound (Fig. 2). The same biological effects measurements are being conducted at the FVP site (Phelps et al., Chapter 00).

There are different levels at which the laboratory-to-field linkage could be made for the biological effects measurements. One level at which this link could be made would be to compare, or correlate, the laboratory effects results conducted under standard exposure conditions

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with the effects measurements obtained from the field. A positive correlation could simply be fortuitous because the degree of comparison between laboratory and field exposure conditions would be unknown. Further, the results obtained from this level of comparison would not be applicable to any other disposal site. Another level at which this link could be made would be to compare laboratory effects results conducted under field-simulated exposure conditions with the effects measurements obtained from the field. Positive or negative correlations could then be related to the ability of the laboratory tests to simulate what occurs in the field. This is what is currently being conducted in the FVP. The exposure assessment component of the FVP provides the information necessary to duplicate field exposure conditions in the laboratory, and also provides estimates of the spatial and temporal variability of the controlling environmental parameters in the vicinity of the disposal site. In addition, this information will be used to develop and validate process models for vertical transport and contaminant phase partitioning at the disposal site. These models will provide a basis for extending the exposure assessment results from this study to other disposal sites.

2.1 Objectives

The general objective of the exposure assessment component of the aquatic portion of the FVP is to develop and field validate quantitative assessment methods for

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relating dredged material inputs to the transport, transformation, and fate of the associated contaminants. The specific objectives are:

1. Determine the environmental exposure field at the biological effects measurement stations in the water column (pelagic zone), in the sediments (benthic zone), and at the near-bottom/sediment-water interface (epibenthic zone) using a combination of field sampling and *in situ* instrumentation.

2. Relate the source (disposal mound) to the near-field exposure measurements using process models for the vertical transport of contaminants and particulate materials.

3. Determine the environmental processes controlling contaminant phase partitioning, as related to bioavailability and contaminant transport and fate.

A discussion on how we have proposed to meet the above objectives is best centered about the conceptual model we are using in the exposure assessment component of the FVP (Fig. 3). The vertical compartments correspond to the various zones in which the effects assessment will be conducted. The dredged material on the disposal mound,

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along with the associated contaminants in the particulate and dissolved phases, is considered to be the source input. This material can be resuspended by a combination of various processes, such as tidal currents and wind-generated waves. Repartitioning of the contaminants betweeen the dissolved and particulate phases can result as the dredged material is mixed with background material. This material can be distributed vertically in the water column and transported horizontally by the water motion. Subsequently, the material can be deposited and again resuspended and transported horizontally. Continuously in this process, the contaminants are repartitioned between the dissolved and particulate phases. Consequences are an exposure field which can vary near-continuously in space and time in the vicinity of the disposal site. This exposure field needs to be quantified in a way which is compatible with the information requirements of the effects assessment measurements.

The field sampling plan, discussed in the next section, is designed to measure the environmental exposures where the biological effects assessments are being conducted. The sediment exposures are determined by analyses of sediment cores collected at various horizontal locations and at time periods of months to seasons (corresponding with the cruise sampling periods). The water column exposures are determined by (1) field sampling for contaminant and

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suspended solids concentrations at various horizontal stations, at different vertical levels in the water column, and at time periods of months to seasons; and (2) continuous deployment of in situ instrumentation by the University of Connecticut (Bohlen, 1982) for determination of suspended solids concentrations one meter above the bottom at a single station, with burst sampling intervals of 15 minute separation. One meter above the bottom corresponds with the deployment depth of caged mussels used as one biological measure in the effects assessment field work (Phelps et al., Chapter 00). The near-bottom/sediment-water interface exposures are determined by an in situ instrument, the acoustic profilometer developed by Ohio State University (Bedford, 1982). The acoustic profilometer measures suspended solids concentration profiles from a point one meter above the bottom to the sediment-water interface, at approximately one cm intervals. This provides the information for the field work with organisms that live near the sediment-water interface.

Models for vertical transport of material are being developed from laboratory flume experiments at the University of California, Santa Barbara, to account for both physical and biological processes which affect the flux of material across the sediment-water interface (Lick, 1982, 1984). The laboratory experiments will be validated with

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data obtained by the *in situ* instrumentation and by benthic surveys conducted with the REMOTS benthic camera (Rhoads and Germano, 1982). The linkage between laboratory and field results will be strengthened through the use of a device that has been developed for measuring sediment resuspension parameters in the field (Lick et al., 1984).

Laboratory experiments are being conducted at Manhattan College (DiToro and Horzempa, 1982; DiToro et al., 1982) to develop process models for phase partitioning and adsorption/desorption of BRH contaminants under the conditions at the FVP site in both the water column and the sediments. Emphasis is being placed on the degree of reversibility of contaminant desorption, and on the effects of suspended solids concentration on the observed partition coefficient. Field sampling analyses for BRH contaminants will be used to validate these process models.

2.2 Field Data Acquisition

A summary of the relevant field information that is being obtained as part of the exposure assessment component of the FVP is indicated in Table 1. The appropriate scales for this project are at two basic levels. The first corresponds to the scale of interest for the effects assessment measurements, i.e., the time frame over which the biological effects tests are conducted and the regions which the pelagic, epibenthic, and infaunal organisms inhabit. Measurements made on these scales are actually bulk

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Table 1. Field and laboratory data acquired for the exposure assessment component of the Field Verification Program.

	Water Column	Sediment	Biota
Physical	in situ instruments: turbidity, temperature, salinity, currents, waves benthic camera imagery laboratory flume experiments: resuspension parameterization cruise data: suspended solids, temperature, salinity, DO tides water levels meteorolgical information satellite imagery disposal records	side scan sonar: bathymetry bulk analysis: grain size, water content diver observations benthic camera imagery laboratory flume experiments: sediment resuspension parameterization box cores bottom shear stresses: from in situ instrumentation	effects of biota on physical properties of sediments
Chemical	metals organics partition coefficients	metals organics total organic carbon	pelagic epibenthic infaunal
Biological		benthic camera imagery box cores diver observations	

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measurements because they do not contain information on the processes which occur at smaller scales, but rather reflect an integrated measure of what occurs on these smaller scales.

The second level involves the scales at which the controlling dynamic processes actually occur. It has become evident only in the past few years that these processes, such as those which control the interactions at the sediment-water interface, occur on scales which are quite small. For example, Heathershaw (1976) determined from measurements in the Irish Sea that as much as 70% of the turbulent energy production in the bottom boundary layer occurred in about 5% of the total time of record, with an event duration of 5-20 seconds. This means that the physical processes which resuspend sediment at the bottom do no act continuously, but occur as intense bursts randomly spaced in time. Only when measurements are made on these scales over which the actual processes occur can one understand what bulk measurements really mean, and then develop a correct parameterization of these processes for use at the bulk scale level.

The other consideration of scales for the acquisition of data is the variablility in the actual environmental system. The field program has been designed to determine the variability that occurs at different scales: subtidal, tidal, monthly, and seasonal. The vertical variability was

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investigated by sampling for selected parameters at one meter intervals. The horizontal variability was investigated by placing sampling stations in a cross fashion about the disposal mound (Phelps et al., Chapter 00) as shown in Fig. 4. The biological effects measurement stations are the center of the mound (CTR), 200 meters east of CTR (200E), 400 meters east of CTR (400E), 1000 meters east of CTR (1000E), and the south reference station (SREF). The 200E station is located on the flank of the mound, 400E is on the fringe of the mound, 1000E is a kilometer away in the predominant tidal direction, and SREF is a reference station used as a control in this study. Additional sampling stations were located around the mound so that parameters could be measured during the cruises as the tidal flow came over the mound and transported material into the surrounding area, i.e., there were upstream and downstream stations relative to the mound irrespective of the tidal flow direction.

2.3 Data Synthesis

The emphasis during the initial phase of the exposure assessment component of the FVP is on determining the field exposure conditions for the pelagic, epibenthic, and infaunal organisms. This information is required to conduct laboratory effects assessment tests under simulated field exposure conditions. The basic parameters required to do this are suspended solids concentrations and the particulate

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and dissolved concentrations of the contaminants present at the disposal site. In addition, information is required on ambient environmental conditions and their natural variability.

The emphasis in subsequent phases on the exposure assessment component will be on development and validation of internally consistent functional relationships for describing processes which control vertical distributions of contaminants and particulate material at the disposal site. These controlling processes are summarized in Table 2. These vertical distributions are hypothesized to be controlled through the following chain of causal linkages:

1. Wind speed and direction.

2. Horizontal water motion (including those tidally induced) and vertical dispersion.

3. Shear stress at the sediment-water interface.

4. Flux of particulates across the sediment-water interface.

5. Partitioning (adsorption/desorption) of contaminants between dissolved and particulate phases.

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Table 2. Controlling processes for distribution of contaminants and particulate material

Process	Components or Compartments
Chemical Partitoning	Water Column
	Sediment
Biological Uptake	Water Column
	Infaunal
	Epifaunal
Sediment-Water Interactions	Physical
	Biological
Vertical Transport	Water Column
	Sediment
Horizontal Transport	Water Column
	Sediment

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The approach will be to develop hypotheses for these linkages, in the form of sub-models, and to test these hypotheses against data from laboratory and field scale measurements.

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3. RESULTS OF FIELD WORK

Approximately 55,000 cubic meters of dredged material from BRH were disposed at the northeast corner of the Central Long Island Sound (CLIS) Disposal Site (Fig. 4) in May 1983. This created a mound approximately 150 to 200 meters in radius, in water with a depth of 20 meters. The height of the disposal mound was approximately one to two meters at the center. The central part of the disposal mound was found to be composed of sand-size particles mixed with silty material, while the flanks and fringes of the mound were composed entirely of extremely fine-grained material.

The composition of the central part of the disposal mound is different from the material collected from BRH prior to the dredging operation (Rogerson et al., Chapter 00). This material was collected with box cores and homogenized to provide a stock supply of BRH sediment for the laboratory effects assessment experiments (Dillon, 1984). It is hypothesized that either the extremely fine portion of the BRH material to be dredged from the harbor was not fully collected by the clamshell dredges used, or it remained in suspension upon disposal and was then transported away from the site by tidal currents. In the latter case, the heavier, sand-size particles deposited at the disposal buoy, while a portion of the finer material was deposited on the flanks and fringes of the mound.

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Results of the field work presented here include the physical and chemical information obtained for the water column, sediment, and biota at the study site, before and after disposal. The postdisposal conditions through September 1983 will also be presented, providing a full season of information after the disposal operation.

3.1 Physical Information

Weather data for 1983 from the National Weather Service station at Bridgeport, Connecticut, are presented in Fig. 5. Major storms were present through April and after November; the immediate FVP postdisposal period was relatively quiet in terms of storm activity. A composite of the salinity and water temperature at the surface and one meter above the bottom is presented in Fig. 6. Approximately 90% of the surface and near bottom temperature variation can be accounted for by a yearly harmonic. The rest of the variation is due to daily surface water heating (as much as 4°C) that occurred over a cruise day, and the tidally induced motion of the horizontally inhomogenous water masses in the sound. Fig. 7a shows a series of vertical temperature traces obtained on 22 April 1983. Diurnal surface heating is evident, along with the effect of tidal motion. Fig. 8 shows the sea surface temperature (SST) in Long Island Sound (LIS) at 08:12 Greenwich Mean Time (GMT) on 23 July 1983, derived from the AVHRR sensors on the NOAA 7 satellite. The SST indicates the horizontal

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variation in surface temperature that can occur in the sound. Thermal stratification at the site started in late March (Fig. 6a), coincident with the increase in air temperature (Fig. 5c). Thermal overturn occurred in September (Fig. 6a), coinciding with the seasonal decrease in air temperature (Fig. 5c).

From Fig. 6b, it appears that the surface water salinity is consistently lower than the bottom water over the entire year. This is consistent with the basic estuarine circulation that exists in Long Island Sound (Riley, 1956). Denser, more saline oceanic waters flow through the eastern end of the sound along the bottom, mix with freshwater runoff that enters along the coastline, and flow out the sound through the eastern end at the surface. The sharp decrease in salinity in March coincides with the large surface runoff into the sound from the major tributaries in Connecticut (Fig. 9). As with the temperature, the large salinity variation that occurs over a cruise day (Fig. 7b) is due to the tidally induced motion of the horizontally inhomogeous water masses in the sound. This yearly picture of temperature and salinity variations in the sound is in agreement with that observed by Riley (1956).

The variations that occur in vertical profiles for light attenuation over a day are indicated in Fig. 7c. The decrease in light attenuation, which corresponds with

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lower suspended solids concentration, that consistently occurs between 5 and 10 meters is coincident with the pycnocline level (Fig. 7a and 7b). The light attenuation that occurs below 10 meters is due to the tidal resuspension of bottom material and the mixing of this material below the pycnocline. The pycnocline acts as a barrier to upward movement of this resuspended bottom material. The temporal variation is due to the variation in magnitude of the tidal currents. The decreased light attenuation in the surface waters is due to the surface primary productivity occurring at this time in the sound.

Results from a seven day predisposal deployment of the in situ instrumentation on 18-26 April 1983 are shown in Fig. 10 for one meter above the bottom at station 1000E (Bohlen and Winnick, 1984). The small scale temperature and salinity variations over this period are on the order of 1°C and 0.5 parts per thousand, respectively (Fig. 10a and 10b). Oscillations due to tidal, inertial, and internal wave motions can be seen. The background level of suspended solids at the site during this time was approximately 5 mg/liter (Fig. 10c). Excursions from this mean level range up to about 9 mg/liter. These excursions are predominantly due to tidal motions, with storm activity responsible for some of the increased levels. The first four tidal harmonics (M2, S2, K1, and O1) account for over 88% of the variation in the observed currents in Fig. 10d

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and 10e, which is consistent with the work of Swanson (1971). The residual currents, produced by subtracting out the first four tidal harmonics, are shown in Fig. 10f and 10g. The corresponding wind record from the Bridgeport weather station is shown in Fig. 10h.

During the disposal operation, the in situ instrumentation was located at station 1000E, 1 km east of the disposal buoy. The suspended solids record during the disposal period (26 April to 23 May 1983) is shown in Fig. 11. Two things are evident in this figure. The first is that the background level in suspended solids concentrations is on the order of 15 mg/liter. The second is the series of sharp spikes that exceed 30 mg/liter. The increase in background level at 1000E is probably due to a combination of the large amount of dredged materal disposal that was in progress at the CLIS disposal site (approximately one million cubic meters of dredged material was disposed at the CLIS disposal site in April and May of 1983) and of the large influx to the sound of suspended material from the storms that occurred during this period (41% of the 1983 water year tributary runoff into the sound occurred in April and May of 1983). The sharp spikes in the records represent the passage of disposal plumes that were transported past the instrumention array (Bohlen and Winneck, 1984). These are plumes from material disposed at the FVP site as well as from other concurrent disposal

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operations in the southwest corner of the CLIS disposal site. The origin of these spikes was confirmed by comparing the records of the disposal operations with data on the currents. The background of suspended solids returned to normal levels by June.

3.2 Trace Metal Chemistry Information

The water samples for trace metal chemistry analysis were collected when the vertical traces were taken for temperature, salinity, and light attenuation. Duplicate samples were collected for total, as well as particulate and dissolved, contaminant concentration analyses. Samples were also collected for the determination of suspended solids concentration. The samples that were collected for particulate and dissolved analysis were filtered with .45 micron Nucleopore filters on board the vessel within one hour of sampling. Details on sample preparation and analysis are provided in Lake et al. (1983).

Sediment samples were collected by a Smith-MacIntyre grab sampler. Initially, samples were scraped out of the surface of the grab and stored in collection bottles. Starting in July 1983, cores were taken from the Smith-MacIntyre grabs using three inch ID acrylic plastic tubes. All sediment samples were frozen until analyses were conducted. The initial samples were homogenized and subsampled for analysis. The cores were sectioned, homogenized, and then subsampled for analysis. The

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sectioning performed so far has been 0-2 cm (surface sample) and 5-10 cm (subsurface sample). The samples were split and used for both trace metal and organic chemistry analyses. The details of sample preparation and analysis are given in Lake et al. (1983).

The infaunal organism used for chemistry analysis, Nephtys incisa, was collected by sieving Smith-MacIntrye grabs through 2.0 and 0.5 mm sieves. In most instances, sufficient biomass was obtained so that both trace metal and organic analyses could be performed. Caged mussels deployed one meter above the bottom (Phelps et al., Chapter 00) were used also for chemistry analyses. The populations subsampled for chemistry analyses were used also in the field portion of the effects assessments tests for the FVP. The details for the polychaete and mussel sample preparations and analyses are given in Lake et al. (1983).

The primary trace metals that have been analyzed for include Cd, Cu, Cr, Zn, Pb, and Ni. These are the BRH contaminants that were shown to be at levels elevated above the background in LIS (Rogerson et al., Chapter 00). Table 3 shows a comparison of the trace metal levels between BRH material and sediment collected from the FVP site prior to disposal. The metals that are significantly elevated are Cd, Cu, and Cr, and those slightly elevated are Zn, Pb, and Ni. In addition, analyses were conducted for Fe and Mn. Fe is in equally high levels in both the BRH

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Table 3. Trace metal analysis for Black Rock Harbor material, FVP site sediments collected predisposal, and FVP reference site sediments.[1]

	Black Rock Harbor[2]		FVP Site[3]		Reference Site[4]	
Fe	29600	(809)	20205	(1980)	24400	(567)
Mn	359	(37)	765	(374)	505	(6)
Zn	1200	(59)	145	(10)	161	(3)
Cu	2385	(112)	63	(5)	67	(2)
Pb	378	(16)	52	(6)	50	(1)
Cd	23.4	(0.9)	0.35	(0.15)	0.39	(0.02)
Cr	1431	(77)	51	(7)	18	(0.07)
Ni	139	(4)	24	(1)	30	(2)

[1] Numbers represent mean (standard deviation) in mg/kg.

[2] Material collected prior to dredging operations in harbor.

[3] Composite of stations CTR, 200E, 400E, and 1000E collected on 2 March 1983.

[4] Station SREF collected on 2 March 1983.

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material and LIS sediments and provides a good check on internal consistency. Mn is lower in the BRH material than in the LIS sediments, so should indicate decreased levels when other metals indicate increased values from the BRH material.

Predisposal water column sampling on 22 April 1983 indicated the trace metal levels shown in Table 4. The variation in results for any given metal between any two stations was not significant once account was made for the variation in suspended solids concentration. Since sampling was conducted over a tidal cycle on this cruise day, suspended solids concentrations varied according to the stage of the tide. A regression analysis of the individual metal concentrations against suspended solids concentration gave correlation coefficients greater than 0.9. An example for Fe is given in Fig. 12. The correlation coefficient for Fe is 0.99.

Immediate postdisposal water column sampling on 23 May 1983 indicated a definite BRH contaminant signal in the immediate vicinity of the disposal mound at one meter above the bottom. Fig. 13 shows that the values (mean of two samples) for Cr at stations CTR and 400E were outside of the 95% confidence interval determined from samples taken at the other stations. The samples from other postdisposal cruises have not been analyzed for trace metals at this time.

The predisposal sediment sample results are indicated

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Table 4. Trace metal seawater results for vertical profiles taken on the predisposal cruise on 22 April 1983.[1]

	1 MAB[2]		5 MAB[2]		1 MBS[3]		5 MBS[3]		3 MBS[3]	
Fe	169	(4)	180	(8)	128	(1)	113	(12)	118	(4)
Mn	15	(0.4)	15.7	(1.3)	11.9	(0.1)	8.8	(1)	8.9	(0.4)
Zn	1.8	(0.1)	1.8	(0.01)	1.5	(0.06)	1.5	(0.1)	1.6	(0.1)
Cu	0.63	(0.02)	0.69	(0.06)	0.49	(.003)	0.50	(0.06)	0.66	(0.05)
Pb	0.44	(0.02)	0.44	(0.03)	0.32	(0.01)	0.32	(0.03)	0.39	(0.01)
Cd	0.016	(.001)	0.021		0.14	(.002)	0.008		0.018	
Cr	1.1	(0.1)	1.1	(0.05)	0.97	(0.09)	0.98	(.001)	1.0	(0.2)
Ni	0.22	(0.03)	0.20	(.005)	0.14	(0.02)	0.13	(.002)	0.10	(.004)

1 Numbers represent mean (standard deviation) in micrograms/kg for stations CTR, 400E, 400N, 400S, 400W, and 1000E.

2 MAB refers to meters above bottom.

3 MBS refers to meters below surface.

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in Table 3 and Fig. 14. The values indicate no significant difference between any two station values. The immediate postdisposal samples, collected on 3 June 1983, are shown in Fig. 14. The BRH contaminant signal is clearly evident for Cr and Cu. Fe gives no signal, as expected, and Mn indicates decreased levels. It should be noted that the trace metal levels at the disposal mound are lower than what might have been expected from the analyses on material collected from the harbor prior to the dredging operation. This is possibly due to the fact that most of the metals were adsorbed on the fine fraction of the BRH material which was not found at the center of the disposal mound. Sediment samples collected on 1 September 1983 are shown in Fig. 15. As indicated in the previous section, there were no major storms during the summer of 1983. As a result, only small changes occurred between June and September. Cu is possibly more soluble than Cr, and so indicated more of a loss from the sediments. The results in Fig. 15 indicate that stations 200E and 400E, and possibly 1000E, might have a thin layer of BRH contaminated sediments over the background material.

Postdisposal tissue residues for Nephtus incisa collected on 13 July 1983 are shown in Fig. 16. There are no differences between any two station values. No organisms were collected on the disposal mound (station CTR) because Nephtus incisa had not recolonized at that time.

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Tissue residues for caged mussels deployed for one month periods are shown in Fig. 17. The high values at station 400E in April are probably due to sediment contamination in the organisms, as indicated by the high Fe value (Fig. 17c). The comparisons of the caged mussel values should be done across stations for those mussels deployed during the same time period. There can be a variation between different time periods due to the physiological changes that the mussels go through in a year (Phelps et al., Chapter 00). Mussels out during the disposal operations (May) and immediately after disposal (June) indicated about a two-fold increase in residue levels (Fig. 17a and 17b).

3.3 Organic Chemistry Information

Water samples were collected for organic chemistry analysis to measure total, particulate, and dissolved contaminant concentration levels. Twenty liter water samples were collected in duplicate for analysis of total contaminant concentration. These samples were collected within a 5 minute time span. Concurrent water samples were taken for total suspended solids determinations. The samples for particulate and dissolved analyses were collected by pumping through a 0.1 micron glass fiber filter to collect the particulate fraction, and then through a polyurethane foam plug to collect the dissolved fraction. Normally it took about two hours to filter the 100 liters

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necessary for analysis. Water samples were collected for suspended solids determinations before and after the pumping.

The sediment and biota samples were collected as discussed in the previous section. The extraction and analysis procedures for all of the organic samples are detailed in Lake et al. (1983).

For presentation in this paper, discussion wil be limited to PCBs that have been quantified as Aroclor 1254. The results for the PAHs are similar to those for the PCBs. Predisposal water samples from 7 April 1983 had PCB levels of 0.5 parts per trillion (ppt) one meter above the bottom, and 0.4 ppt at five meters below the water surface. There were no significant differences between the stations SREF and CTR. Fig. 18 shows a time plot of the PCB levels at one meter above the bottom at the stations CTR and SREF. There was an elevated PCB signal after disposal (three times background), which approached background by September. There was no detectable increase in PCB levels in the near-surface waters (five meters below the surface) over the disposal mound.

Partition coefficients for the water column PCBs are shown in Fig. 19 as a function of the suspended solids concentration. The partition coefficients were calculated from the particulate and dissolved fraction values. A regression analysis of the partition coefficient against

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suspended solids concentration indicated no significant variation with the suspended solids concentration over the range of 1 to 15 mg/liter. The 95% confidence limits for the regression are at approximately 10^5 and 10^6 .

The PCB levels in the sediments indicated the same trends as were shown in the trace metal results. There was a distinct BRH contaminant signal in the vicinity of the mound, with little change between June and September. Also, the levels in the disposal mound are lower than what one may have expected based upon the levels in material collected from the harbor prior to dredging. The PCB level in this material was 6.8 parts per million (dry weight) (Rogerson et al., Chapter 00).

The tissue residue values for PCBs in Nephtys incisa are shown in Fig. 20. The predisposal values are uniform across stations. No predisposal organisms were collected at station 1000E. There are elevated levels in the organisms collected at stations 400E and 1000E. There were increased PCB levels in the sediments in September at 400E (four times background) and at 1000E (2.5 times background). The worms collected in September had been exposed to the contaminants from the BRH material for about 90 days.

The tissue residues for caged mussels deployed for one month periods before and after disposal are shown in Fig. 21. As discussed in the previous section, comparisons should be made strictly across stations for a

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given deployment period, not between deployments. The results indicate slightly increased residues after disposal in the vicinity of the mound.

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4. STATUS OF MODEL DEVELOPMENT

Some of the initial results of the data synthesis aspect of the exposure assessment component of the FVP were included in the previous section. For example, the tidal harmonic analysis of the near-bottom current meter data, the regression analyses of water column trace metal concentrations against suspended solids concentrations, and the calculation of water column partition coefficients for PCBs were presented as part of the discussion of the field results. The model validation study results on sediment-water interactions and contaminant phase partitioning are not yet available. Laboratory experiments designed to provide data for these studies are summarized below.

Experiments are being conducted with sediments from the FVP site in annular flumes to identify and quantify the mechanisms and parameters on which entrainment and deposition of sediments depend. These experiments are extensions of previous work with sediments from the Great Lakes (Lick, 1982, 1984), are being conducted with both azoic and biologically active sediments. The experiments with the azoic sediments characterize the physical aspects of the entrainment and deposition processes. The biologically active sediments allow one to then understand the additional role of benthic organisms. No results are available yet from these experiments.

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The device for measuring sediment resuspension parameters in the field (Lick et al., 1984) has had some initial field tests. Extensive laboratory use of the device is currently in progress to characterize the various biologically active sediment parameters before any flume experiments are conducted. The use of the device provides a quick procedure for measuring the relative resuspension parameters without having to run a full-size flume experiment. Laboratory flume experiments with one sediment type typically take three to four months, while experiments with the device take a couple of hours.

Partitioning experiments are underway with the BRH stock material. These experiments are similar to those that have been conducted with freshwater sediments (DiToro and Horzempa, 1982 and DiToro et al., 1982). The initial results for contaminant desorption and the effect of suspended solids concentration on observed partition coefficients are similar to the results for freshwater sediments. An important concern with the experiments performed to date is the oxidation state of the material used. The BRH stock material has been stored at 4°C since collection and has remained in a reduced state. Experiments with the reduced material are difficult to conduct due to the slow oxidation that occurs during the course of the experiments. Experiments are now in progress that will use the BRH stock material that has been completely oxidized

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before use.

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5. SUMMARY

The exposure assessment component of the FVP provides the information to duplicate field exposure conditions in the laboratory and provides estimates of the spatial and temporal variability on the controlling environmental parameters. Also, this information is being used to develop and validate process models for sediment-water interactions and contaminant phase partitioning. These models will provide the basis for extending the exposure assessment results from this study to other disposal sites.

The results for the first full season after the disposal operation indicate that the BRH water column signal was limited to about a month. After this period, both water column values and the tissue residues for caged mussels at one meter above the bottom approached normal levels. The results indicate that there was a BRH signal in the sediments. The BRH material was detectable to about one km from the disposal site after three months, and infaunal organisms one km from the disposal site indicated elevated tissue residues.

The exposure assessment information that has been obtained is presently being used in the laboratory-to-field phase of the biological effects assessment component of the FVP.

ACKNOWLEDGMENTS

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Figure Legends

Fig. 1. The regulatory process for ocean disposal.

Fig. 2. The Field Verification Program laboratory to field link.

Fig. 3. Schematic diagram for conceptual model for the exposure assessment component of the FVP.

Fig. 4. Sampling stations for the exposure assessment component of the Field Verification Program.

Fig. 5. Weather data for 1983 from the National Weather Service station at Bridgeport, Connecticut. (a) Sea level pressure. (b) Wind magnitude. (c) Air temperature.

Fig. 6. (a) Surface and bottom temperature at the FVP site in 1983. (b) Surface and bottom at the FVP site in 1983.

Fig. 7. Vertical traces at the FVP site on 22 April 1983. (a) Temperature. (b) Salinity (c) Light attenuation.

Fig. 8. Sea surface temperature derived from NOAA 7 satellite at 08:12 GMT on 23 July 1983.

Fig. 9. Surface water runoff into Long Island Sound from the major Connecticut tributaries.

Fig. 10. Results from <u>in situ</u> instrumenation for

18-26 April 1983 at one meter above the bottom at station 1000E (after Bohlen and Winnick, 1984). (a) Temperature. (b) Salinity. (c) Suspended solids. (d) North-south component of current. (e) East-west component of current. (f) North-south residual current. (g) East-west residual current. (h) Wind speed at Bridgeport, Connecticut, weather station.

Fig. 11. Suspended solids as recorded by in situ insturmentation for 26 April to 23 May 1983 at one meter above the bottom at station 1000E (after Bohlen and Winnick, 1984).

Fig. 12. Total water column iron concentration as a function of suspended solids concentration from cruises on 22 April and 23 May 1983. The dashed lines indicate the 95% confidence limits from a linear regression analysis.

Fig. 13. Total water column chromium concentration as a function of suspended solids concentration from cruises on 22 April and 23 May 1983. The dashed lines indicate the 95% confidence limits from a linear regression analysis.

Fig. 14. Trace metal results for surficial sediment samples from 3 June 1983. (a) Cr. (b) Cu. (c) Fe. (d) Mn.

Fig. 15. Trace metal results for sectioned sediment core samples from 1 September 1983. (a) Cr. (b) Cu. (c)

Fe. (d) Mn.

Fig. 16. Trace metal tissue residues in Nephtys incisa collected on 13 July 1983.

Fig. 17. Trace metal tissue residues in caged mussels deployed for one month periods one meter above the bottom. (a) Cr. (b) Cu. (c) Fe. (d) Mn.

Fig. 18. PCB water column levels at one meter above the bottom at the stations SREF and CTR. PCBs analyzed as individual isomers and quantified as Aroclor® 1254.

Fig. 19. Water column PCB partition coefficients. Calculated from the particulate and dissolved fraction PCB levels. PCBs analyzed as individual isomers and quantified as Aroclor® 1254. The dashed lines indicate the 95% confidence limits from a linear regression analysis.

Fig. 20. PCB tissue residues in Nephtys incisa. PCBs analyzed as individual isomers and quantified as Aroclor® 1254.

Fig. 21. PCB tissue residues in caged mussels deployed for one month periods one meter above the bottom. PCBs analyzed as individual isomers and quantified as Aroclor® 1254.

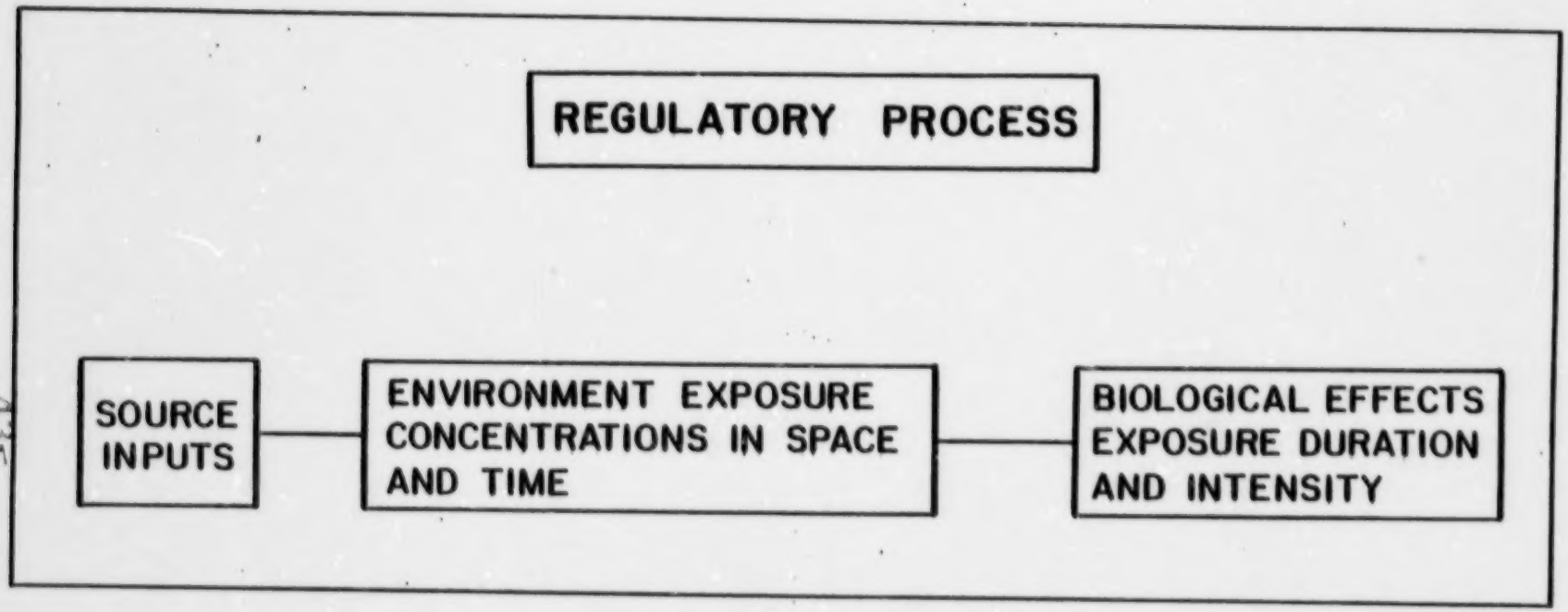
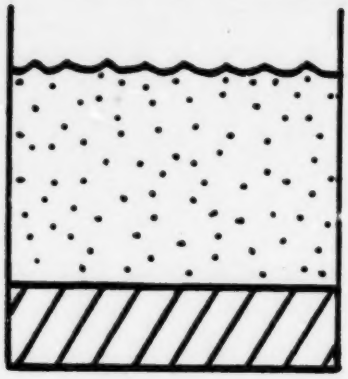

REGULATORY PROCESS
SOURCE INPUTS
ENVIRONMENT EXPOSURE CONCENTRATIONS IN SPACE AND TIME
BIOLOGICAL EFFECTS EXPOSURE DURATION AND INTENSITY

Fig. 1

EPA – COE

FIELD VERIFICATION PROGRAM



LABORATORY
EXPERIMENTAL CONDITIONS

BRH DREDGED MATERIAL
CONTROL SEDIMENT
- SOLID
- SUSPENDED

CENTRAL L.I. SOUND DISPOSAL SITE

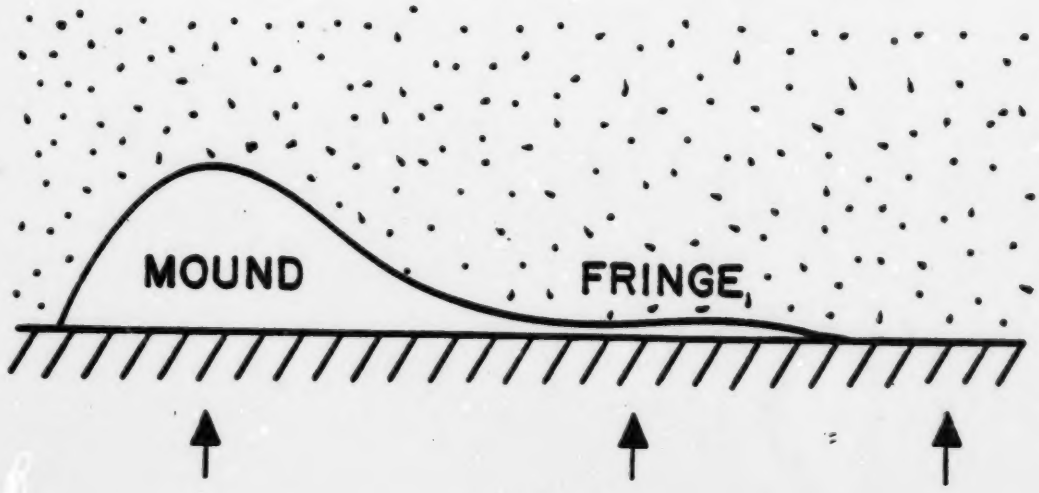


Fig. 2

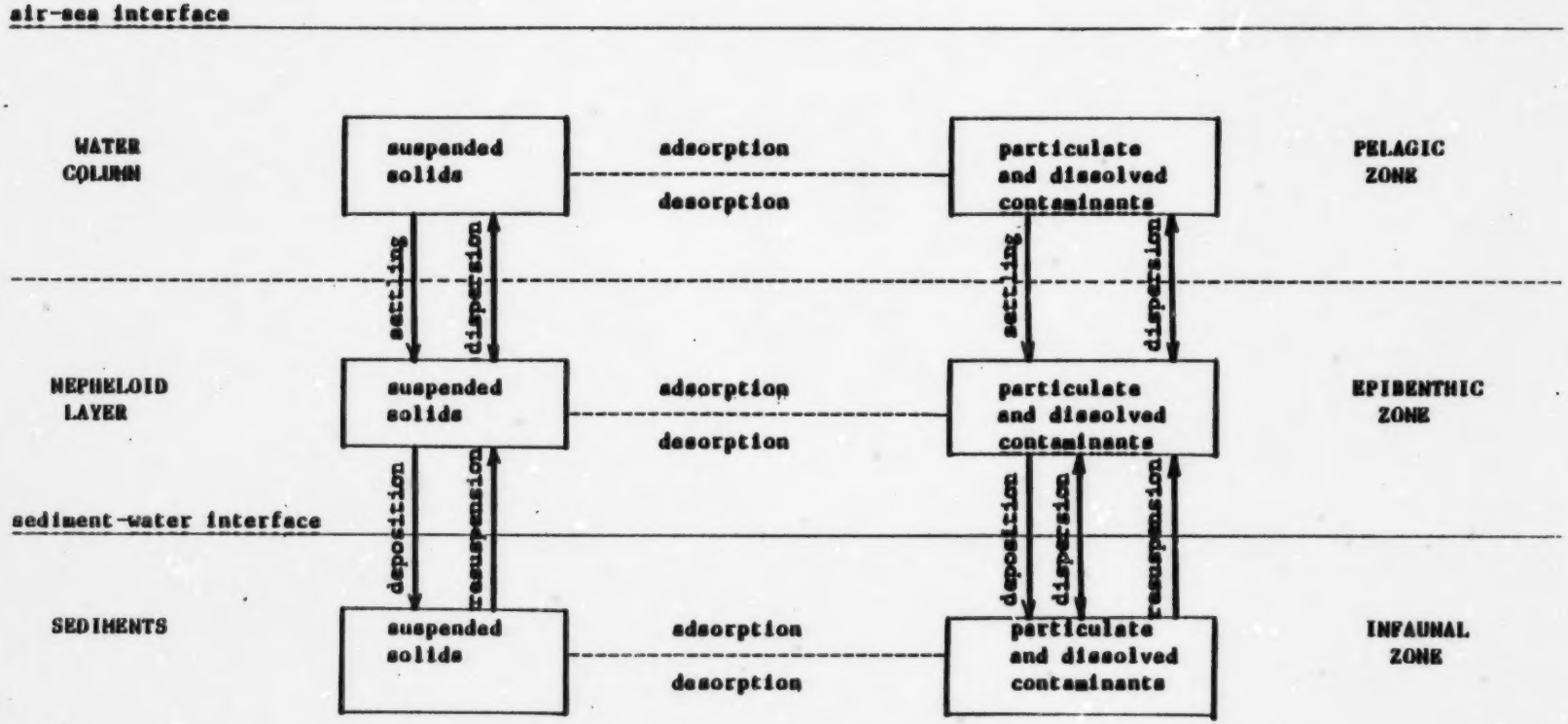
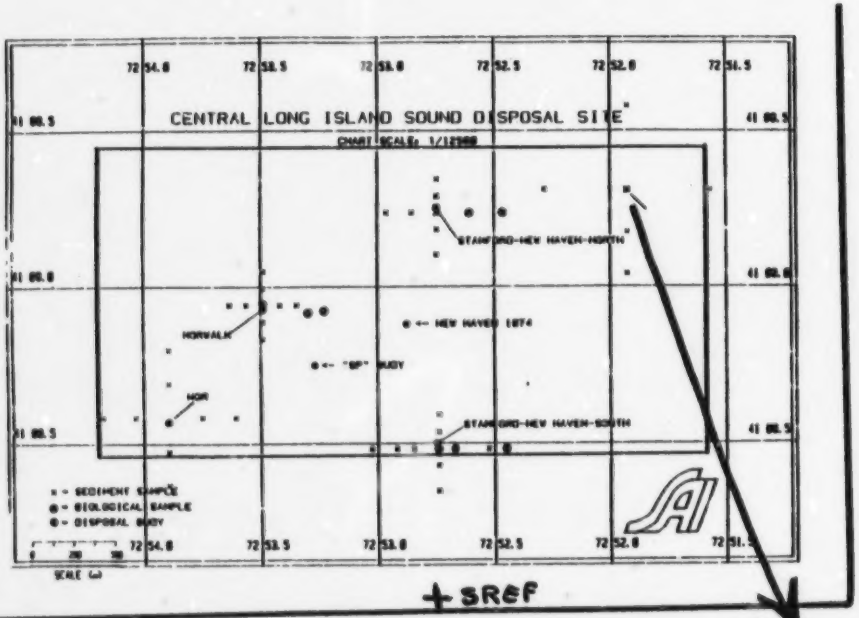
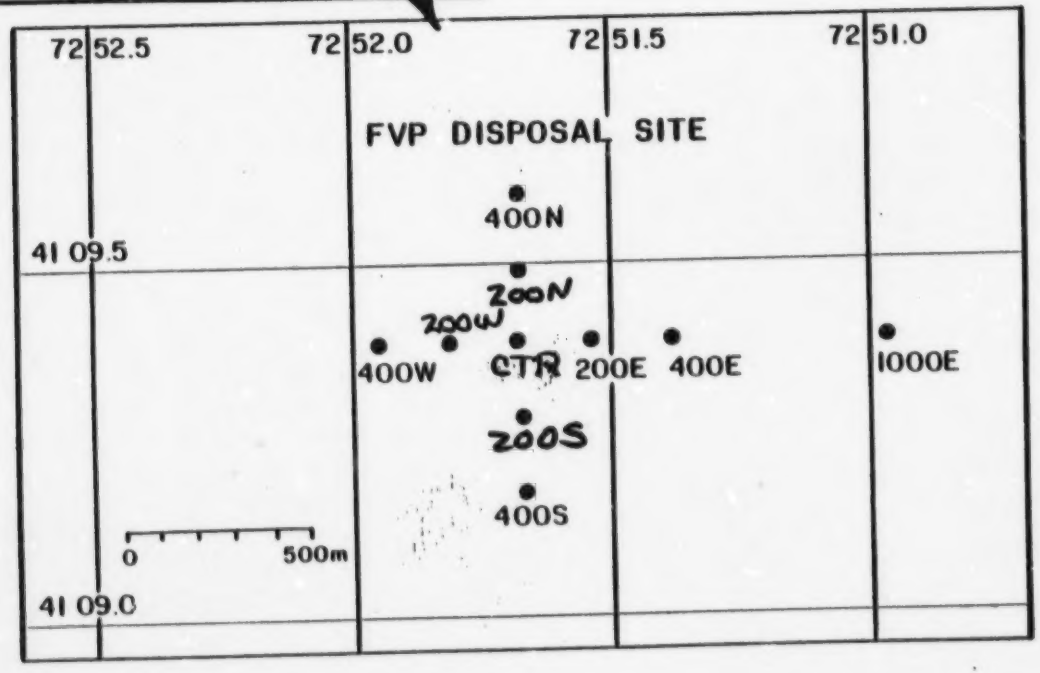

air-sea interface
WATER COLUMN
suspended solids
adsorption
desorption
particulate and dissolved contaminants
PELAGIC ZONE
settling
dispersion
NEPHELOID LAYER
suspended solids
adsorption
desorption
particulate and dissolved contaminants
EPIBENTHIC ZONE
deposition
resuspension
sediment-water interface
SEDIMENTS
suspended solids
adsorption
desorption
particulate and dissolved contaminants
INFAUNAL ZONE

fig. 3


CENTRAL LONG ISLAND SOUND DISPOSAL SITE
CHART SCALE 1/
STAMFORD-NEW HAVEN-NORTH
NEW HAVEN 1874
NORWALK
"SP" BUOY
NOR
STAMFORD-NEW HAVEN-SOUTH
x - SEDIMENT SAMPLE
● - BIOLOGICAL SAMPLE
⊕ - DISPOSAL BUOY
SCALE (m)
72 54.0
72 53.5
72 53.0
72 52.5
72 52.0
72 51.5
41 09.5
41 09.0
+SREF


72 52.5
72 52.0
72 51.5
72 51.0
FVP DISPOSAL SITE
400N
41 09.5
200N
200W
400W
CTR
200E
400E
1000E
200S
400S
0
500m
41 09.0

46

Fig. 4

BRIDGEPORT
1983
S.L. PRESSURE (mbars)
900 925 950 975 1000 1025 1050 1075 1100
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 5a

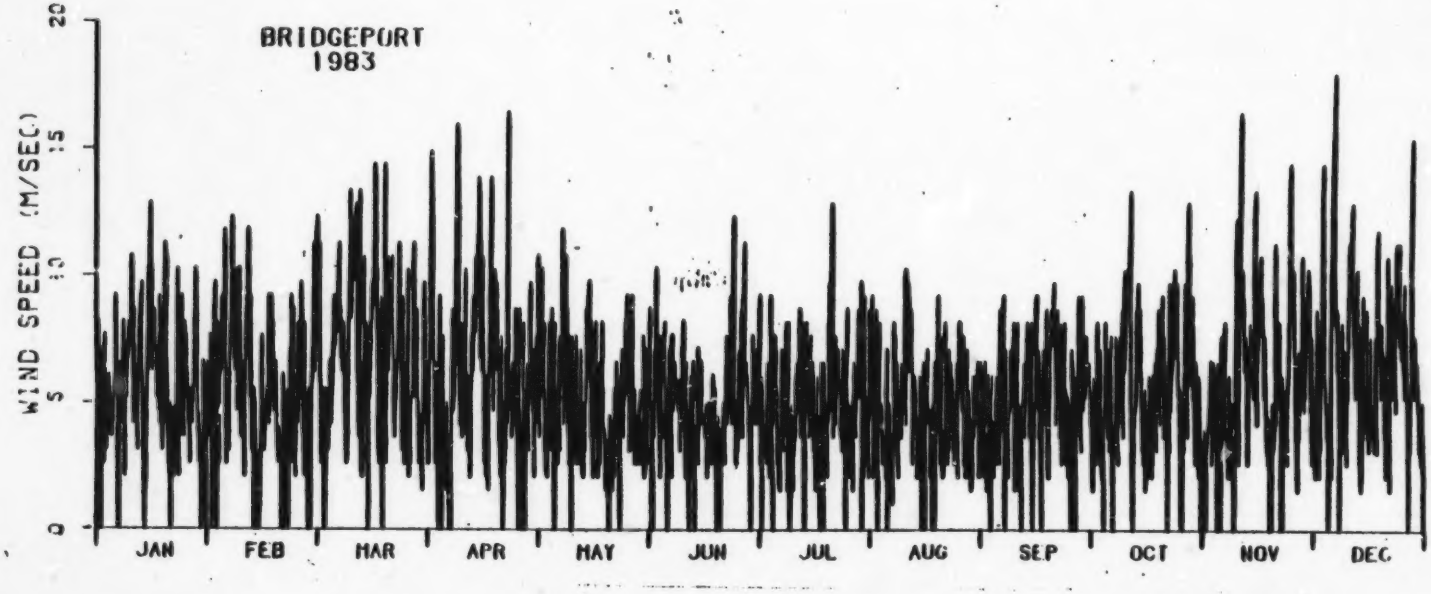

BRIDGEPORT
1983
WIND SPEED (M/SEC)
0
5
10
15
20
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 56

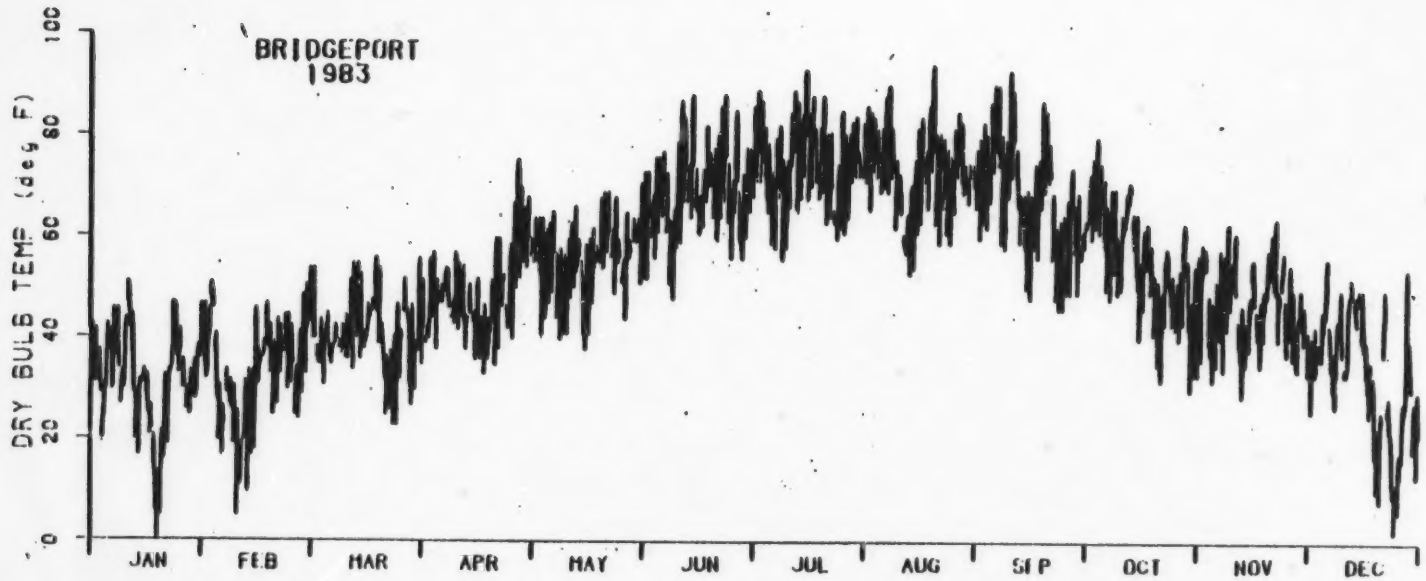

BRIDGEPORT
1983
DRY BULB TEMP (deg F)
0
20
40
60
80
100
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 5C

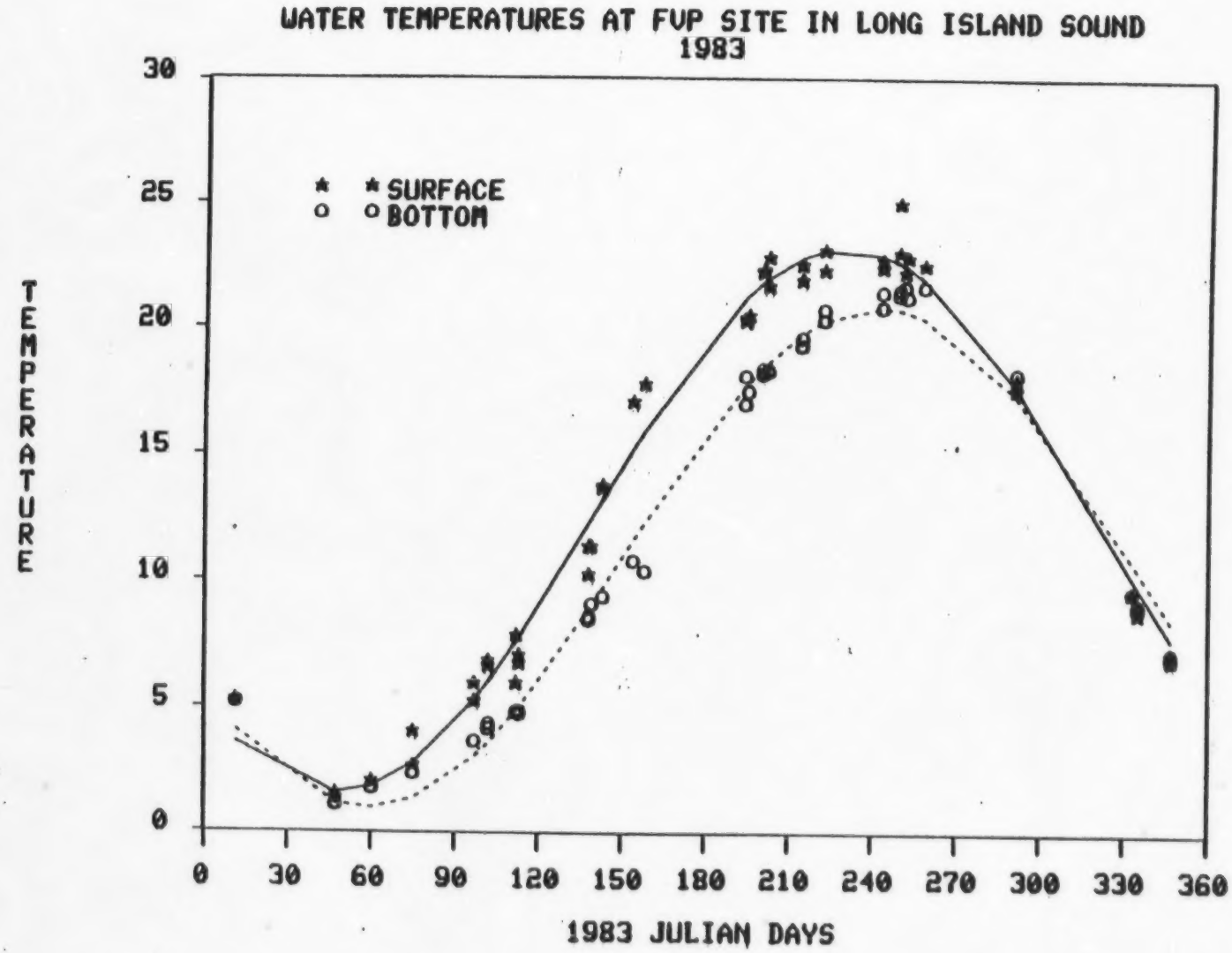

WATER TEMPERATURES AT FVP SITE IN LONG ISLAND SOUND
1983
* SURFACE
o BOTTOM
TEMPERATURE
30
25
20
15
10
5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
1983 JULIAN DAYS

Fig. 6a

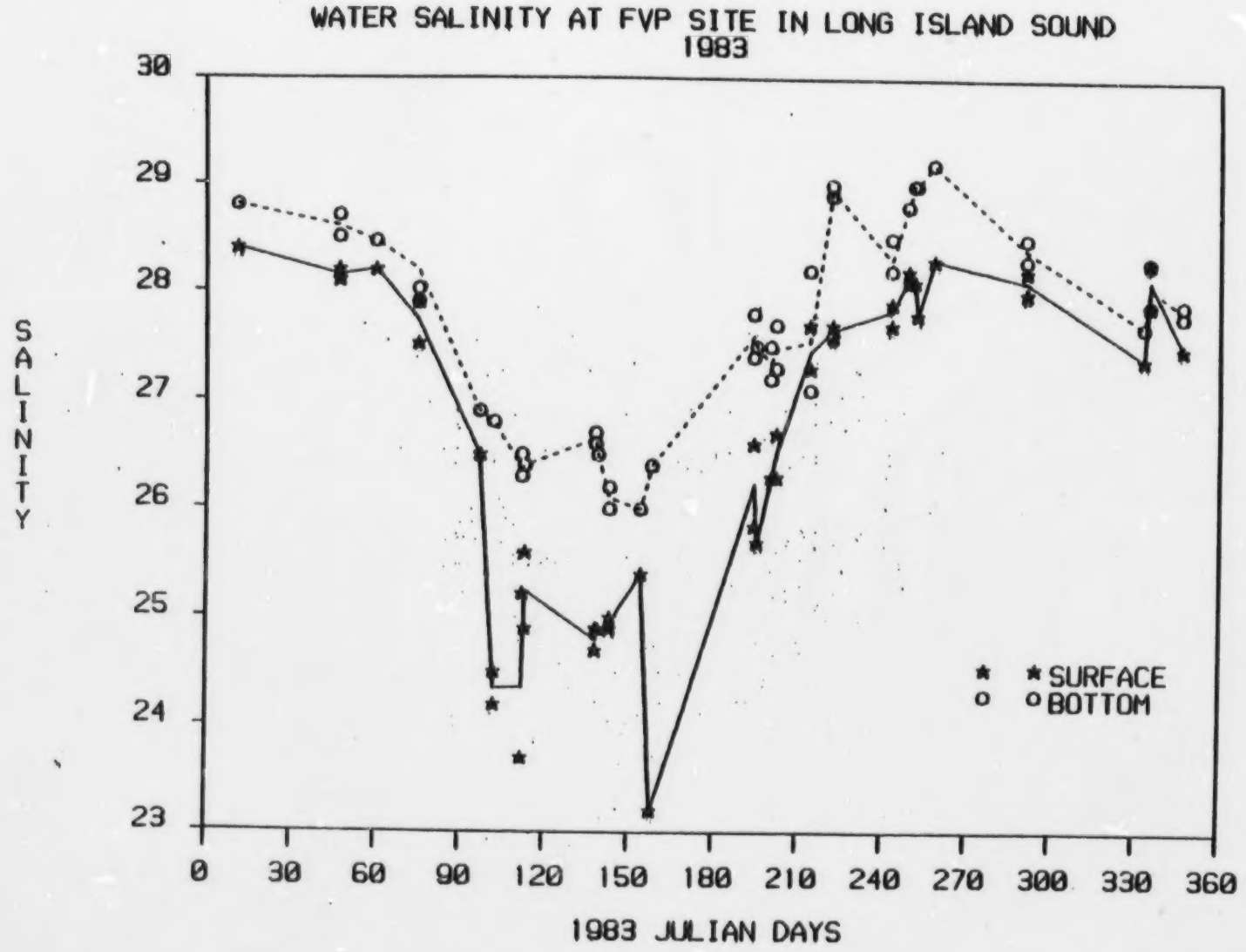

WATER SALINITY AT FVP SITE IN LONG ISLAND SOUND
1983
SALINITY
30
29
28
27
26
25
24
23
0
30
60
90
120
150
180
210
240
270
300
330
360
1983 JULIAN DAYS
SURFACE
BOTTOM

Fig. 66

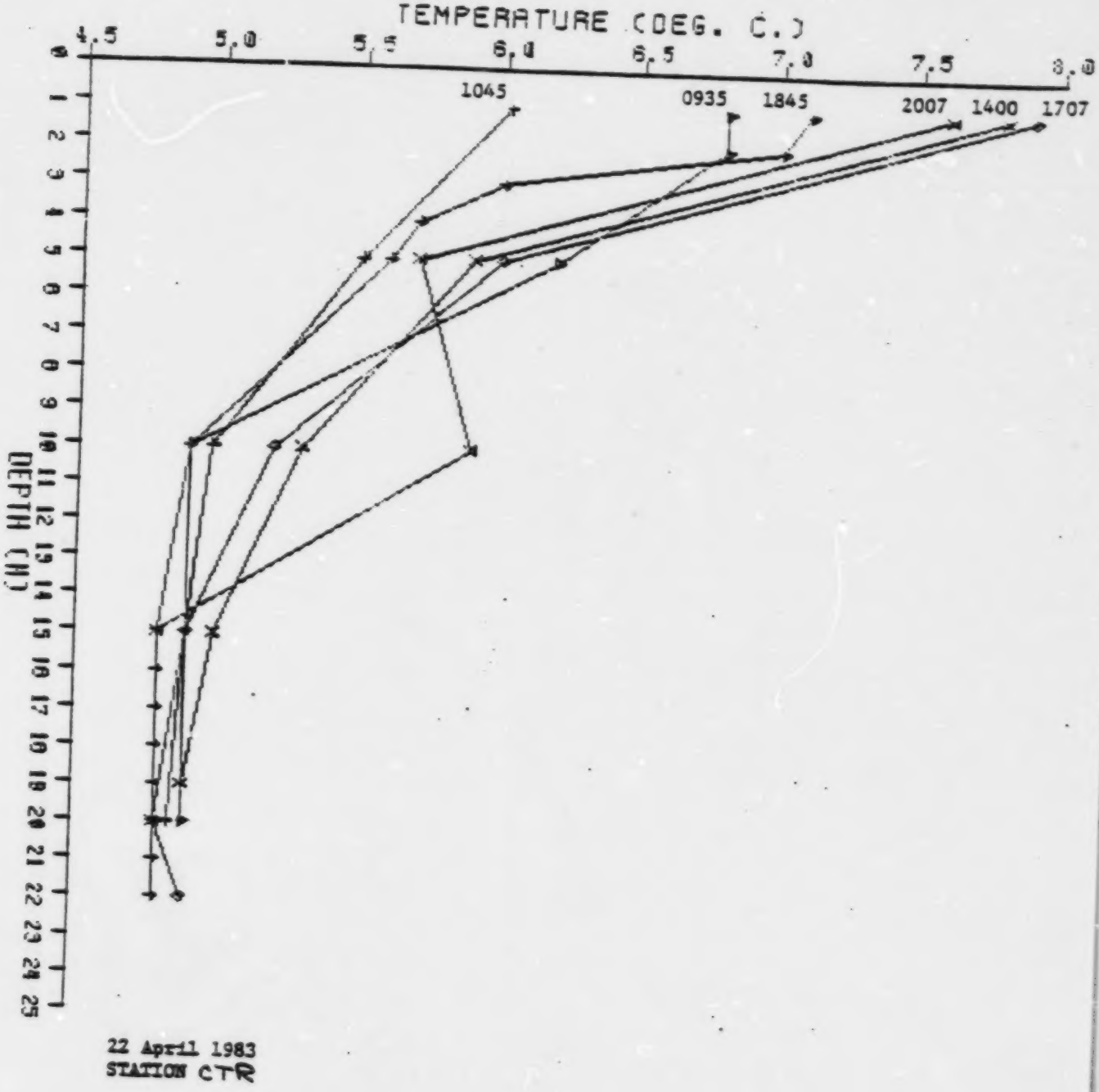
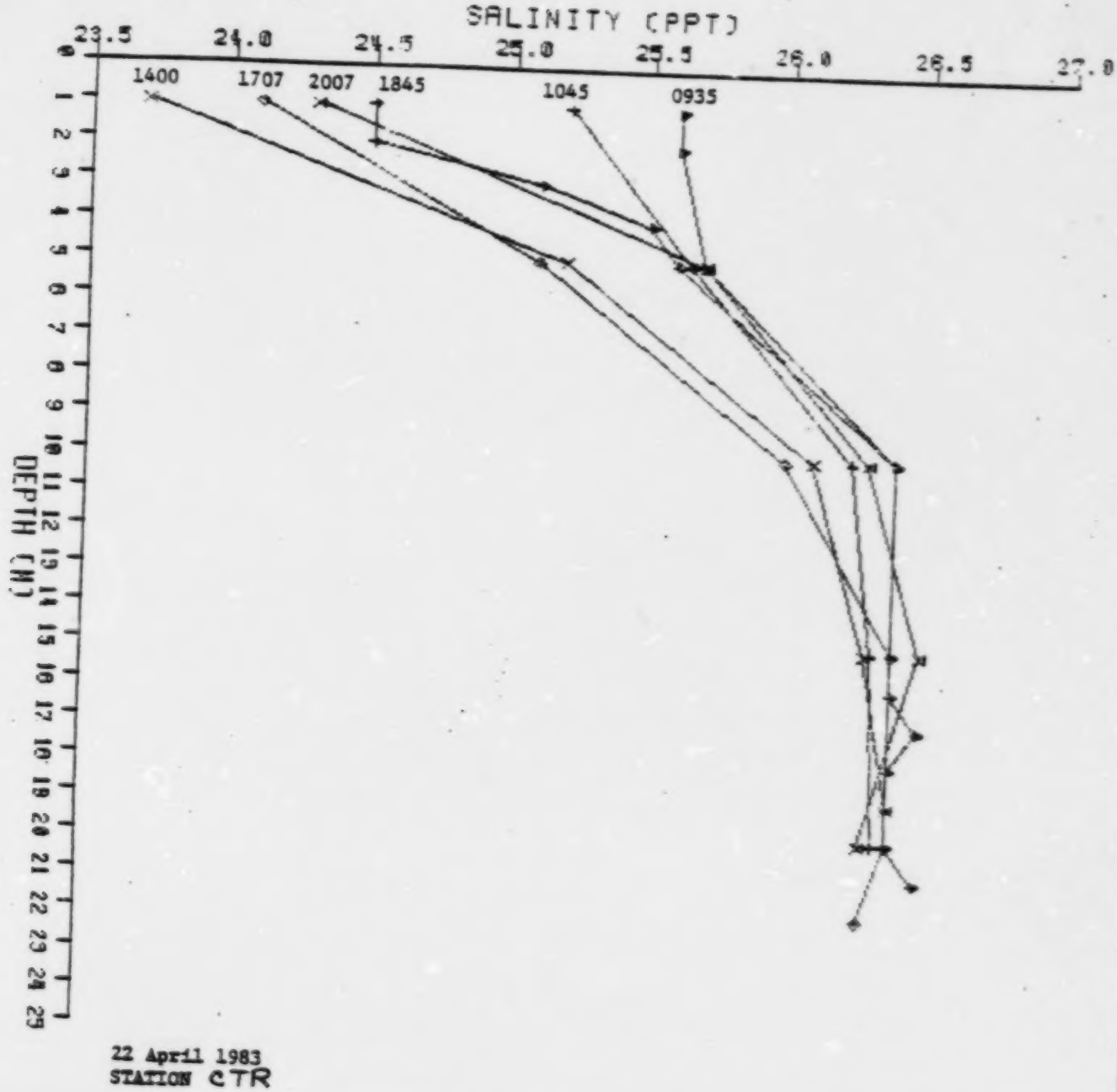

TEMPERATURE (DEG. C.)
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
1045
0935
1845
2007
1400
1707
DEPTH (M)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
22 April 1983
STATION CTR

Fig. 7a



22 April 1983
STATION CTR

Fig. 76

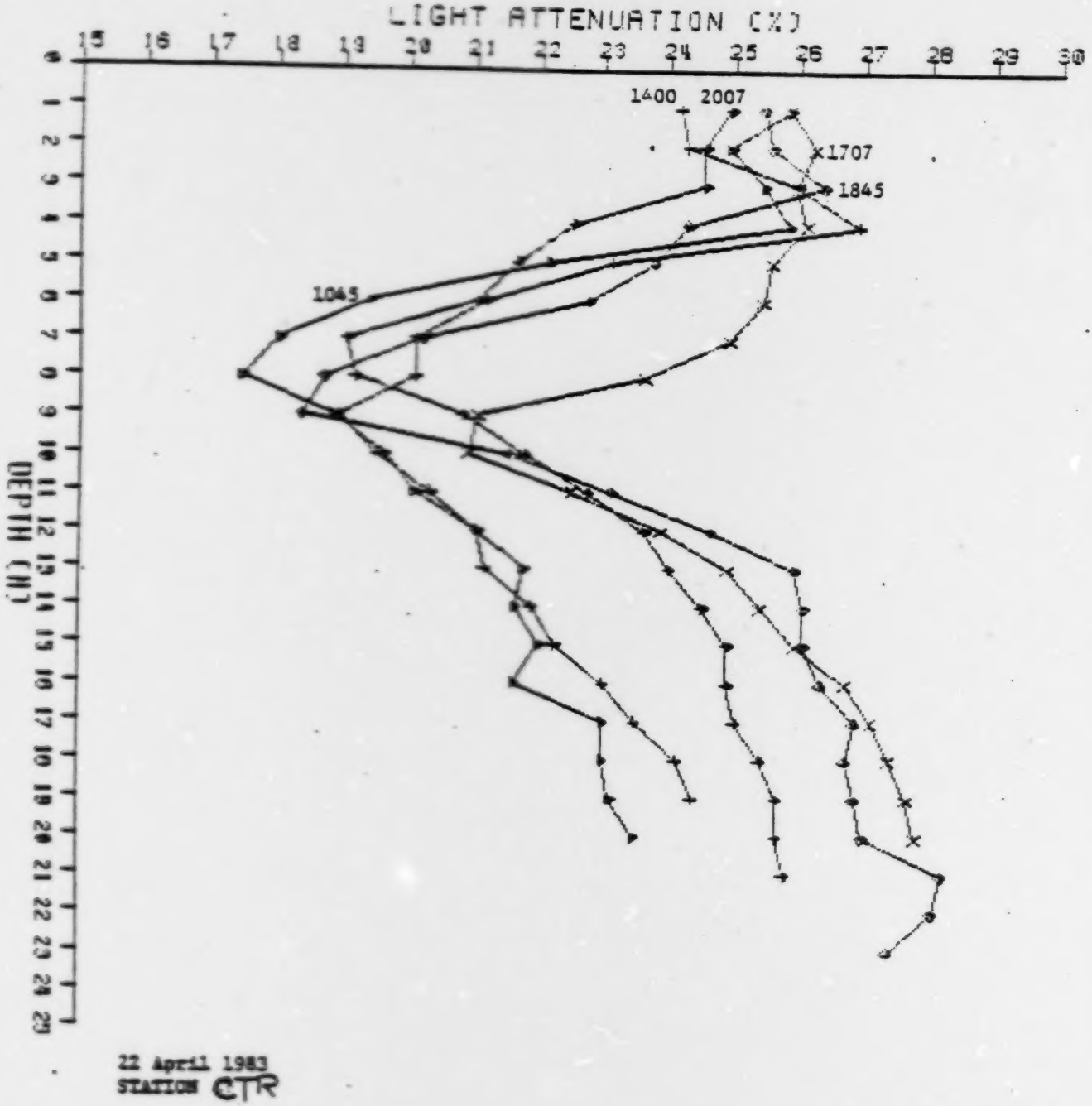
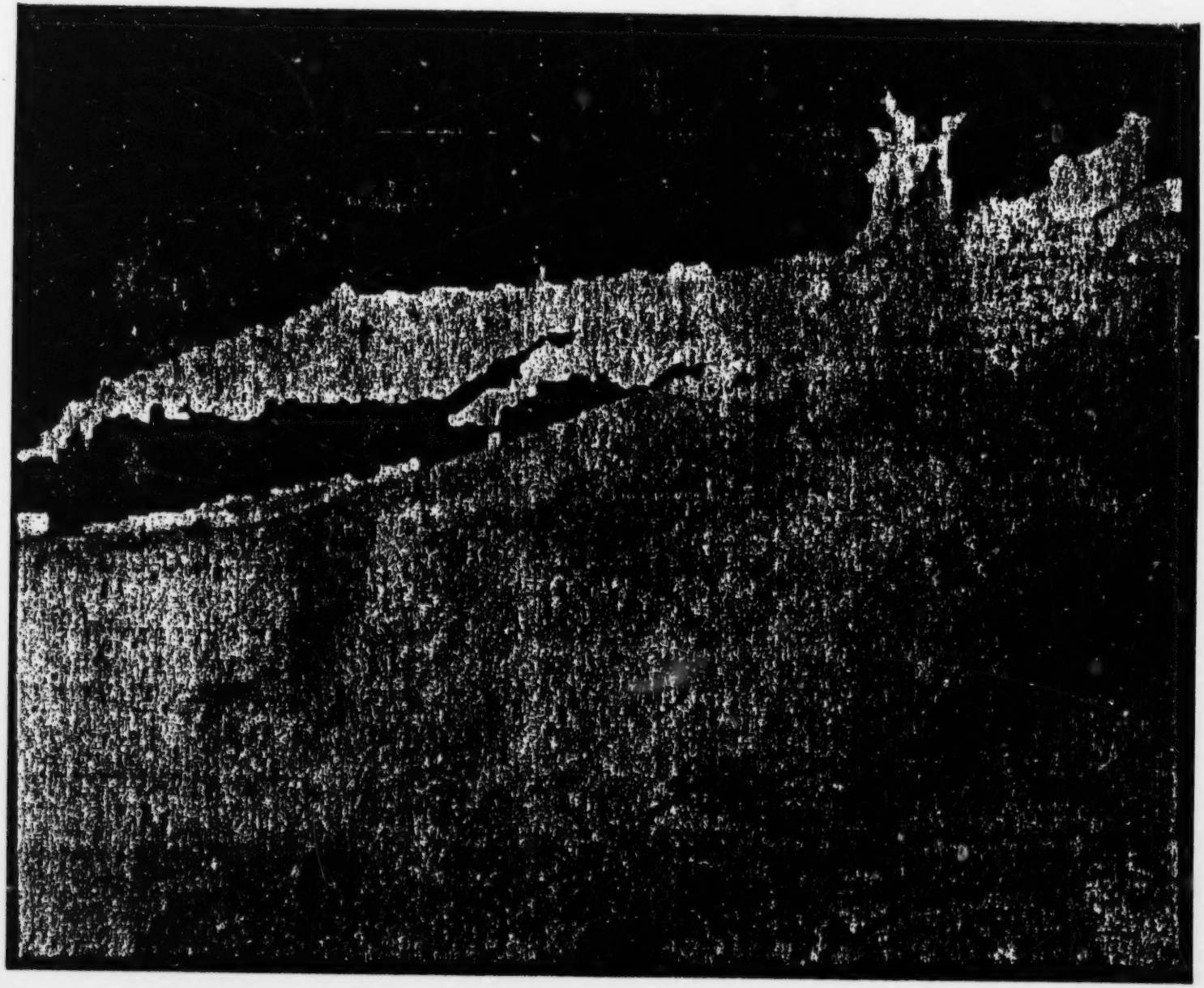

LIGHT ATTENUATION (%)
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
DEPTH (M)
1400 2007
1707
1845
1045
22 April 1983
STATION CTR

Fig. 7C



55A

NOTE TO REVIEWERS:

The contrast in the original image was lost in xeroxing.
The original will be submitted for publication.

Fig. 8

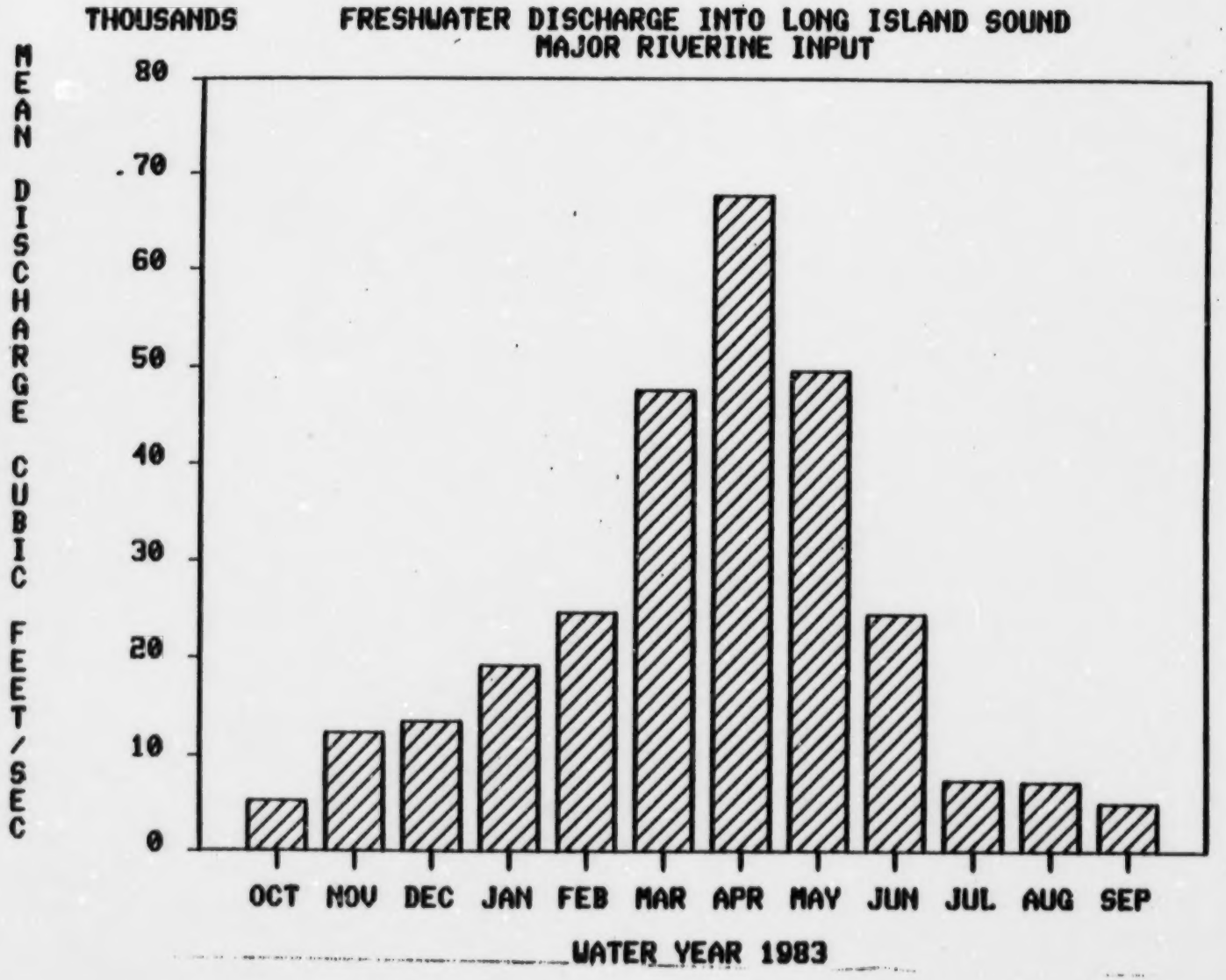

THOUSANDS
FRESHWATER DISCHARGE INTO LONG ISLAND SOUND
MAJOR RIVERINE INPUT
MEAN DISCHARGE CUBIC FEET/SEC
80
70
60
50
40
30
20
10
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
WATER YEAR 1983

Fig. 9

DEPLOYMENT NHDA09

FVP DISPOSAL SITE, NEW HAVEN

INI.=0740 EST, 4/18/83

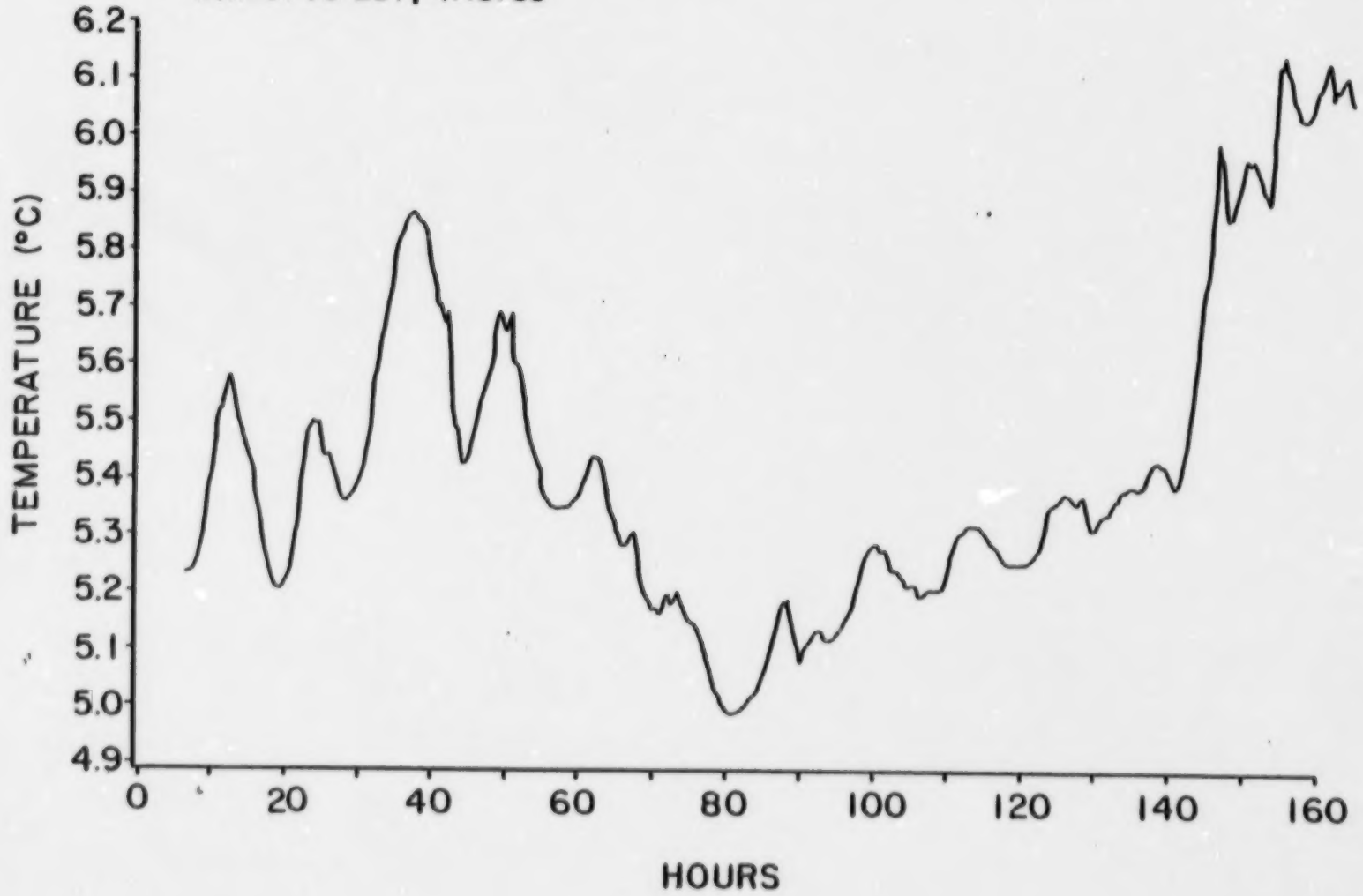


fig. 10a

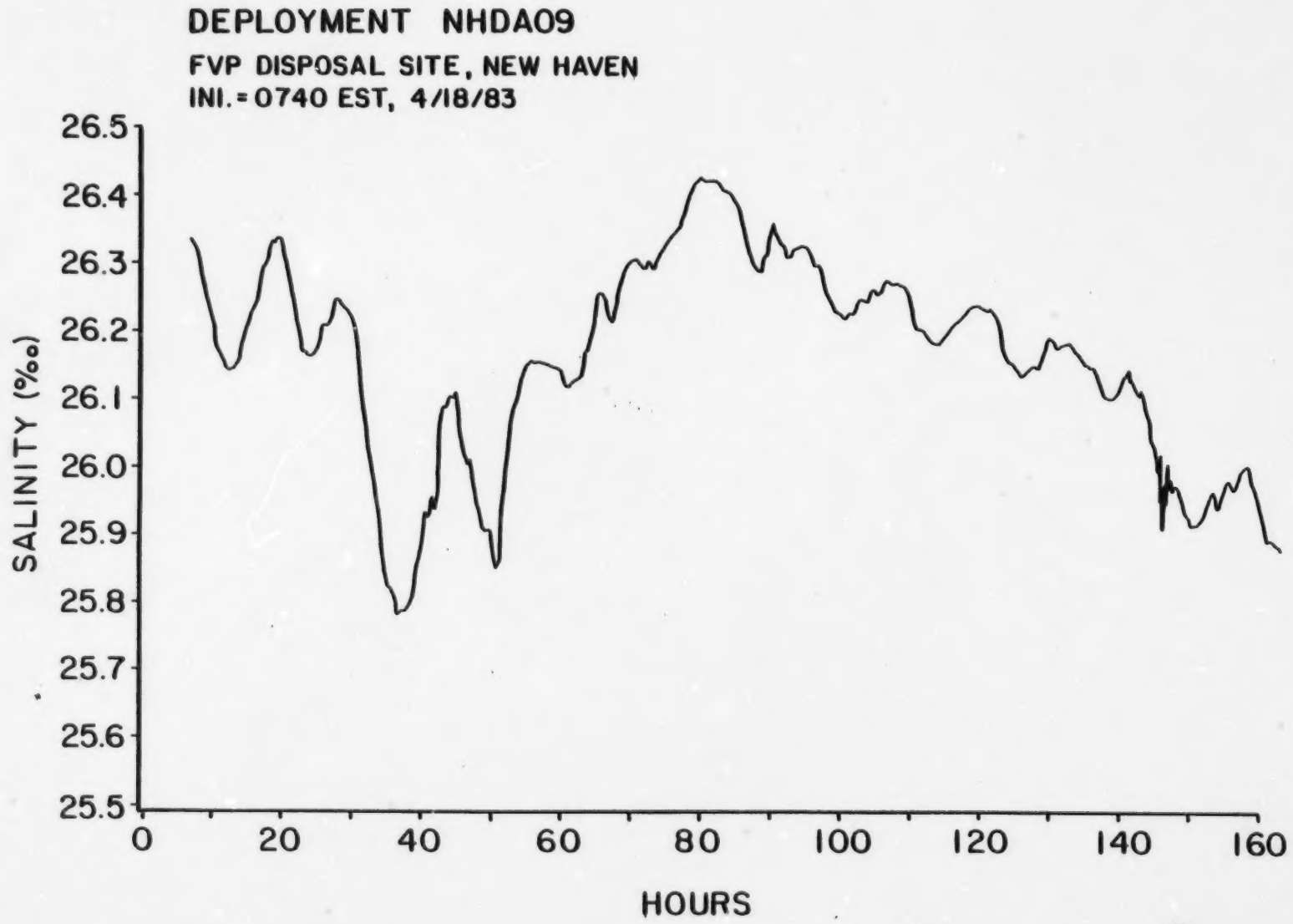

DEPLOYMENT NHDA09
FVP DISPOSAL SITE, NEW HAVEN
INI.=0740 EST, 4/18/83
SALINITY (‰)
26.5
26.4
26.3
26.2
26.1
26.0
25.9
25.8
25.7
25.6
25.5
0
20
40
60
80
100
120
140
160
HOURS

Fig. 10b

DEPLOYMENT NHDA09

FVP DISPOSAL SITE, NEW HAVEN

INI.=0740 EST, 4/18/83

SUSPENDED SOLIDS

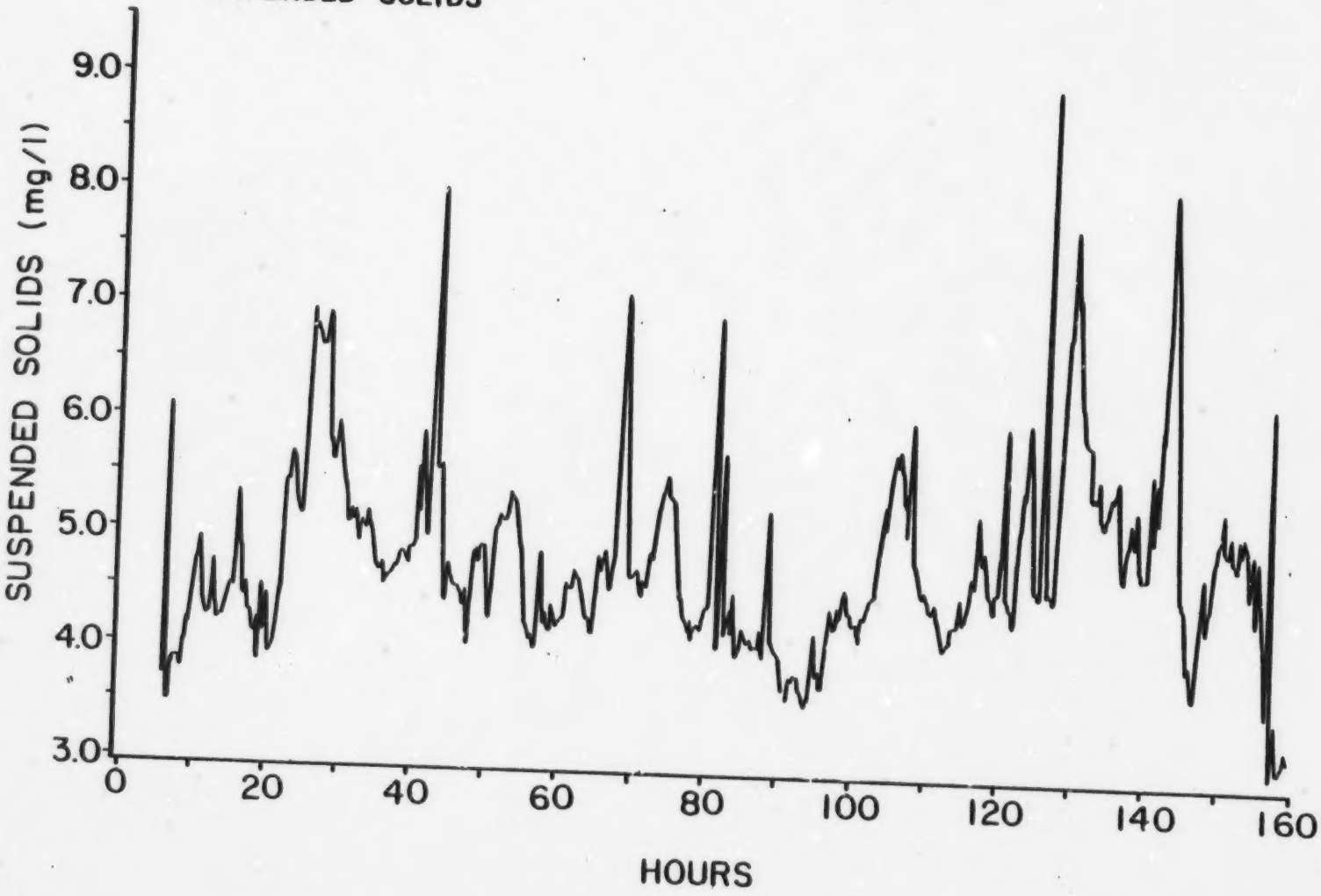


Fig. 10C

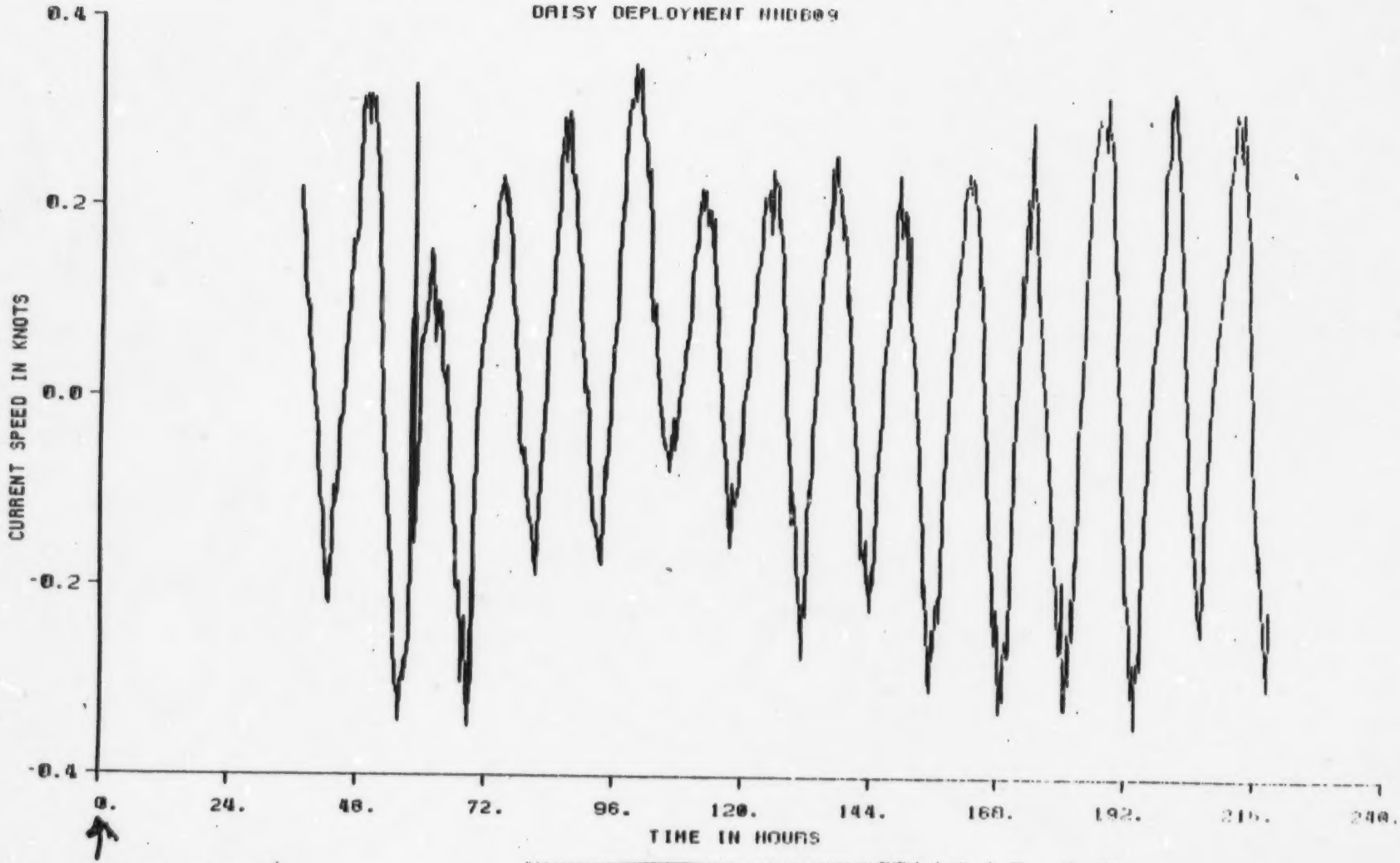

DAISY DEPLOYMENT NHDB09
CURRENT SPEED IN KNOTS
0.4
0.2
0.0
-0.2
-0.4
0.
24.
48.
72.
96.
120.
144.
168.
192.
216.
240.
TIME IN HOURS
April 17, 1984

fig. 10d

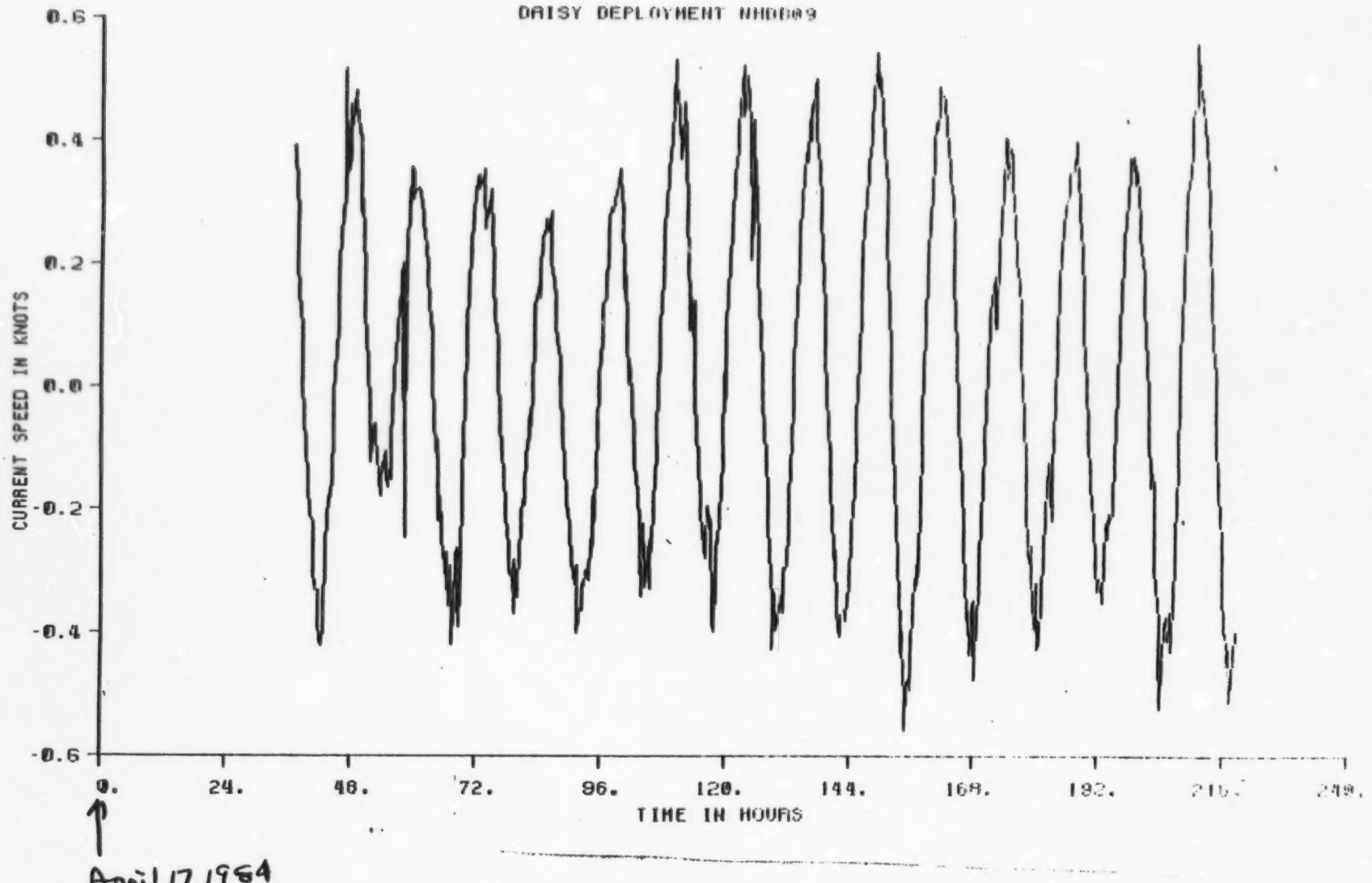
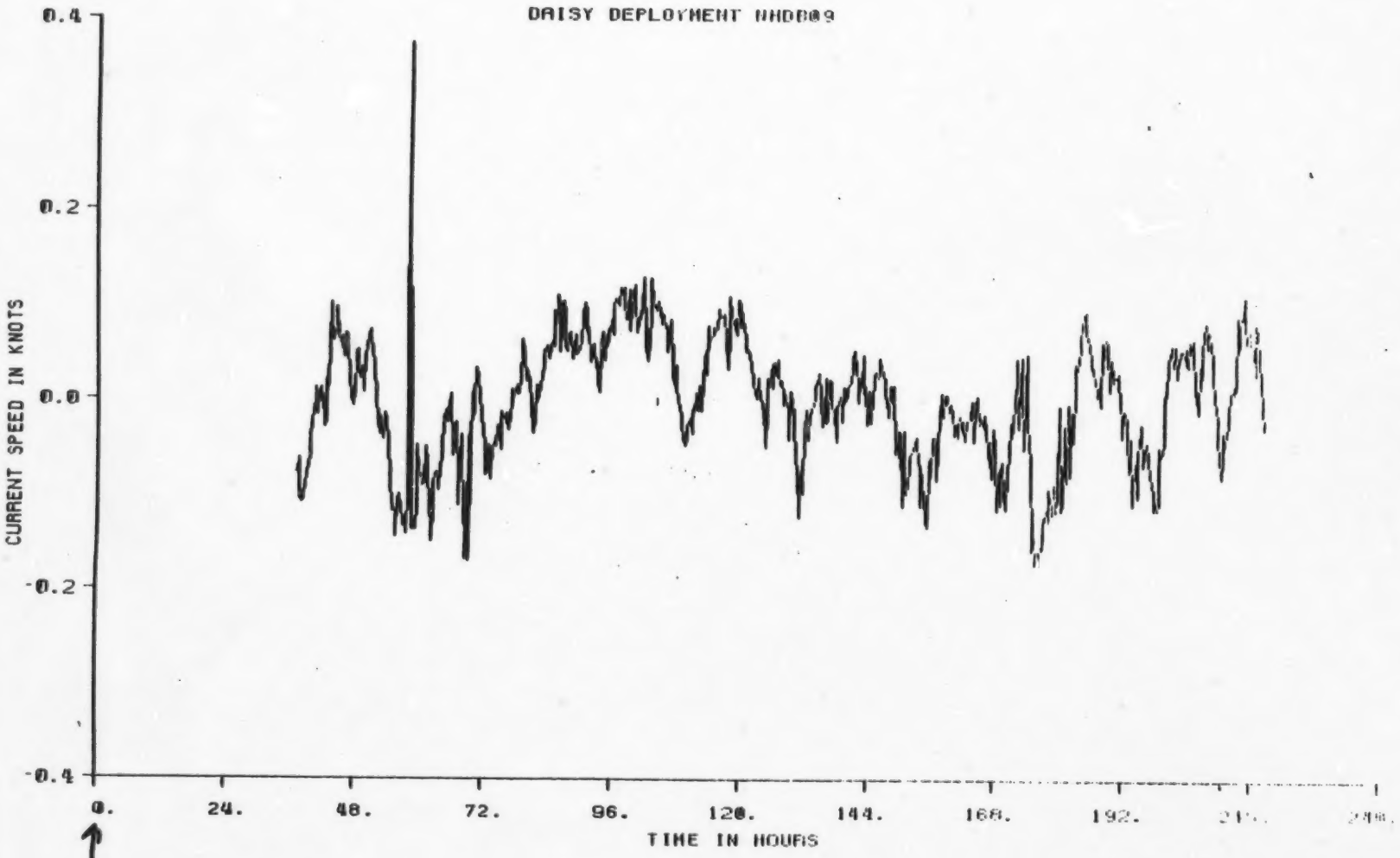
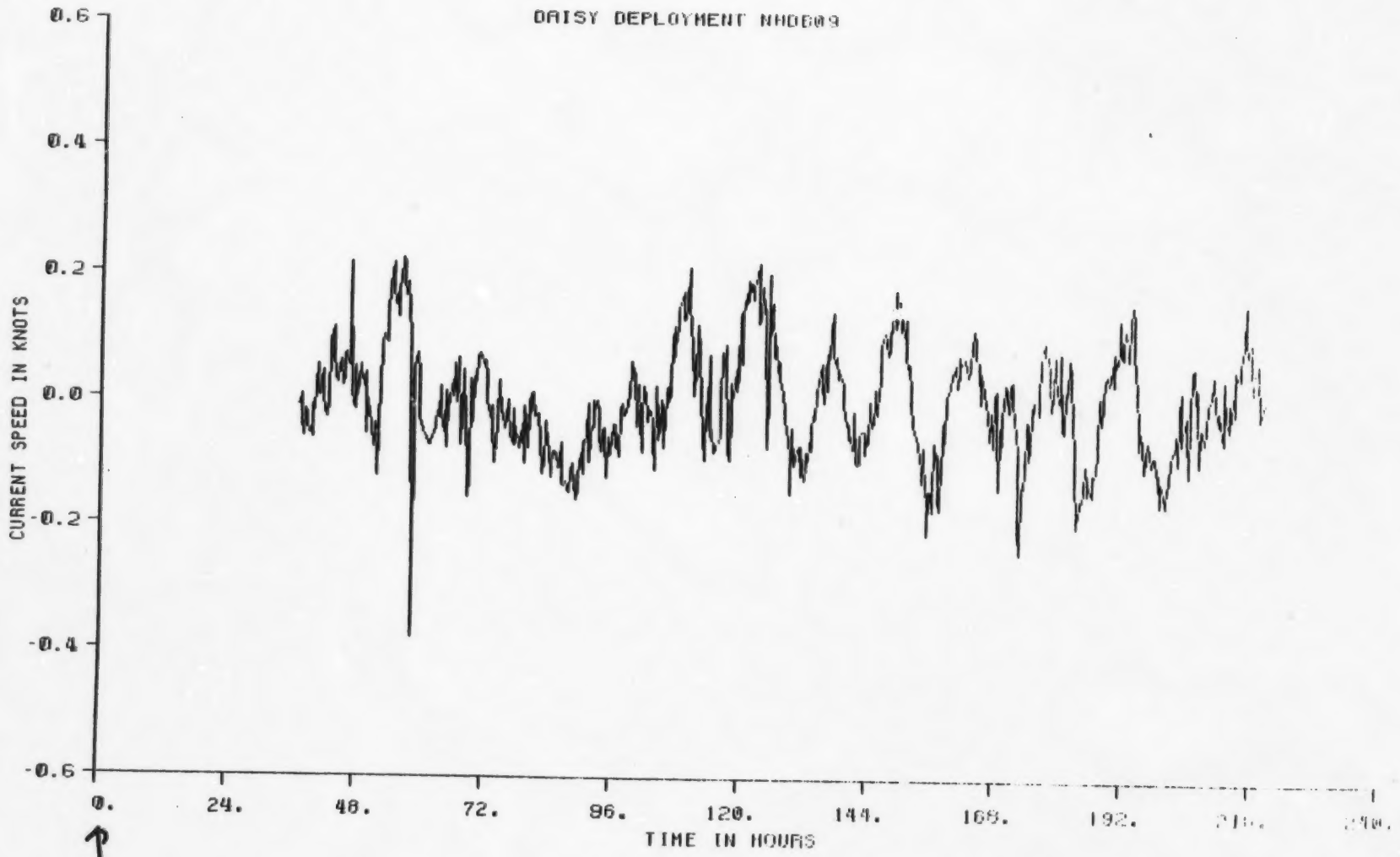

DAISY DEPLOYMENT NHDD#9
CURRENT SPEED IN KNOTS
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.
24.
48.
72.
96.
120.
144.
168.
192.
TIME IN HOURS
April 17, 1964

Fig: 10e



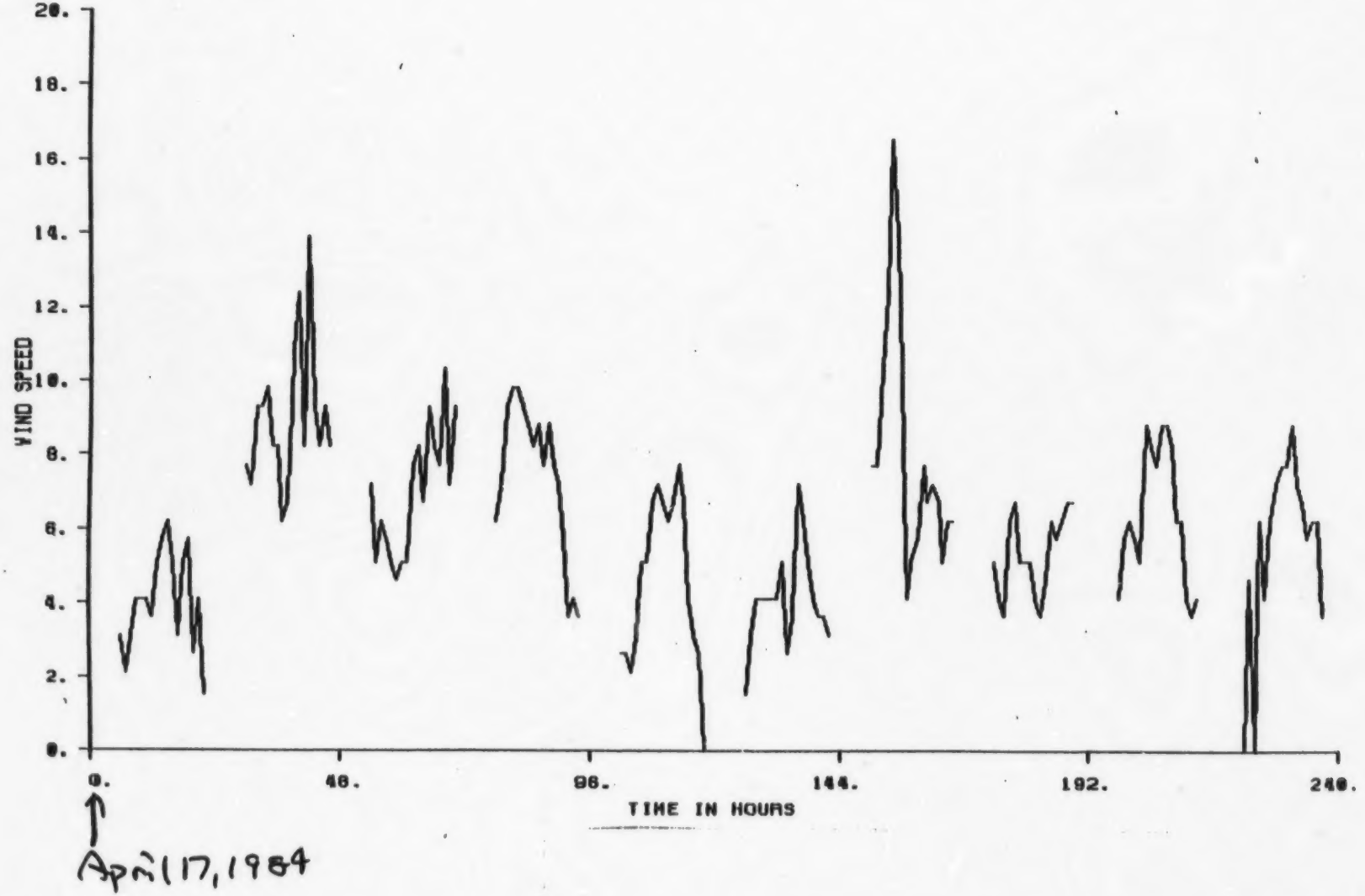
April 17, 1984

Fig. 10f



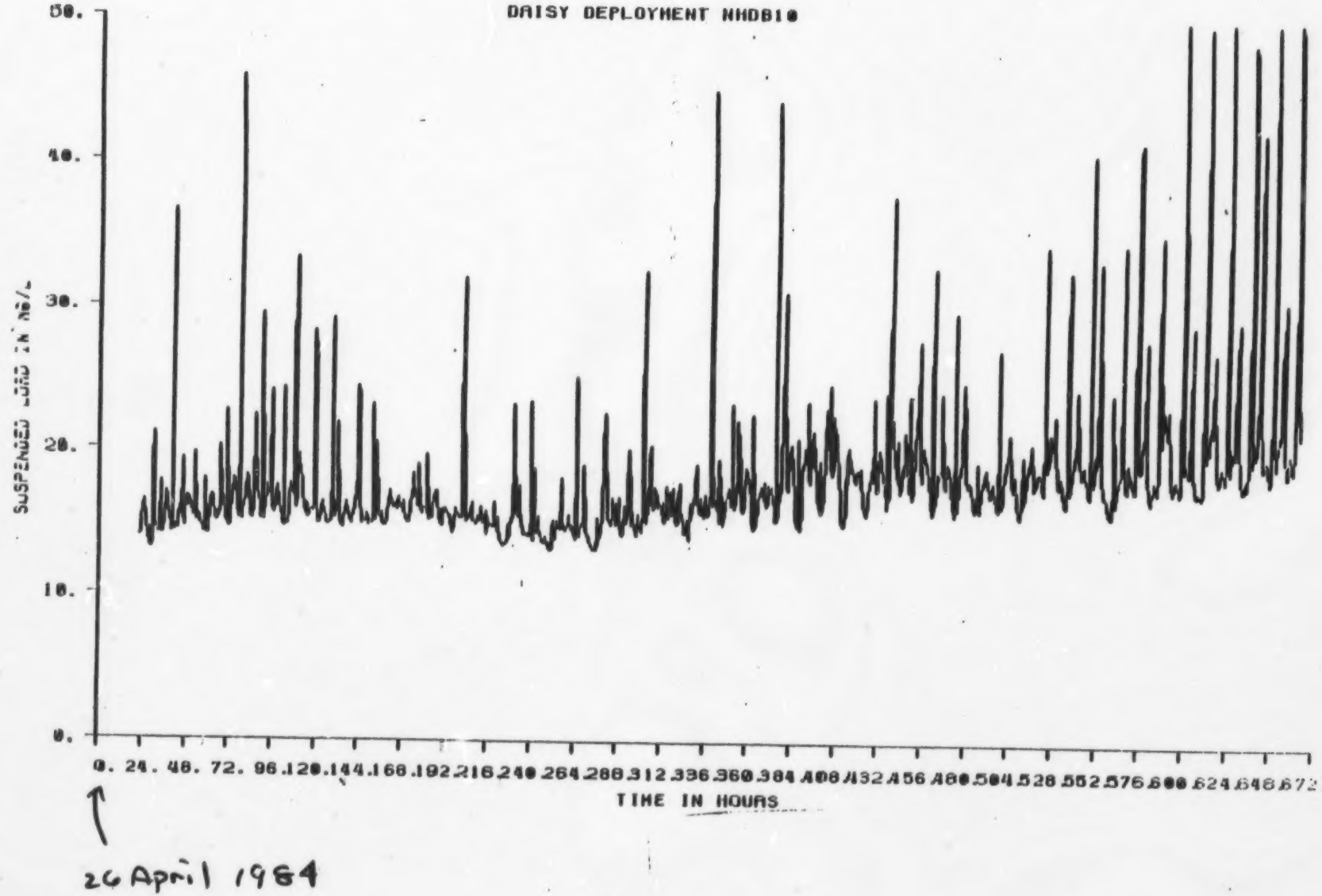
April 17, 1984

Fig. 10g



Apr 17, 1984

Fig. 10h



26 April 1984

Fig. 11

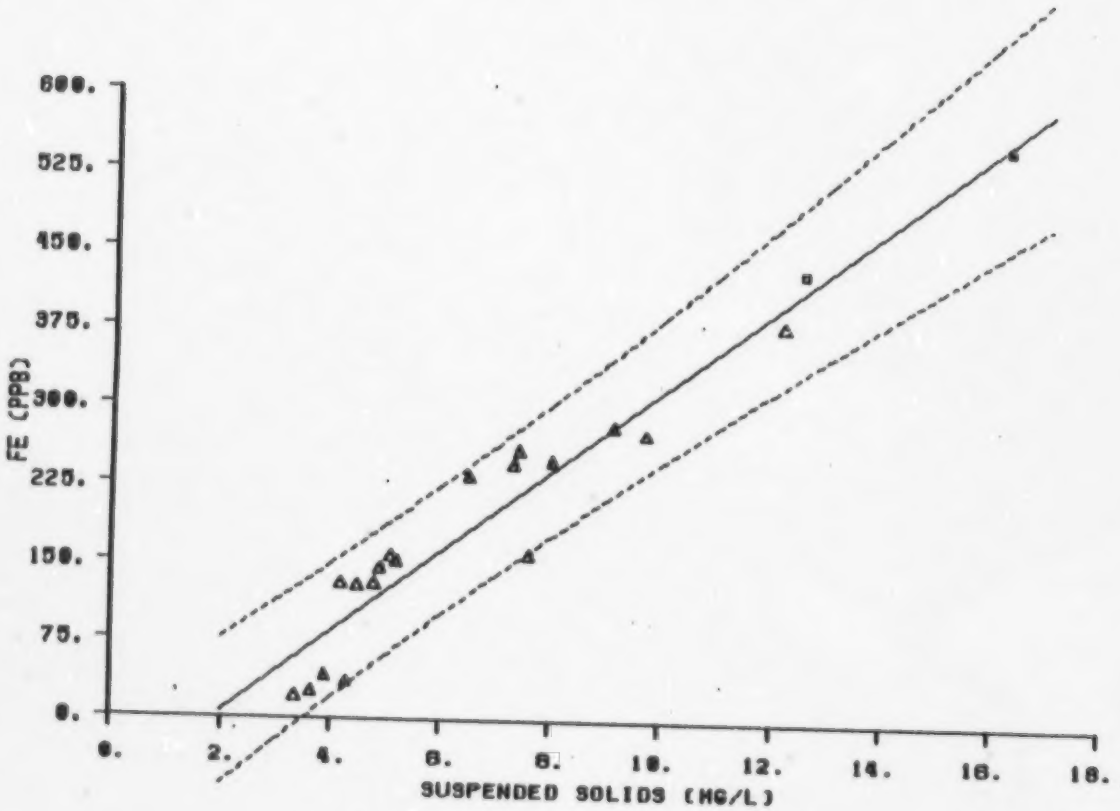

600.
525.
450.
375.
300.
225.
150.
75.
0.
FE (PPB)
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SUSPENDED SOLIDS (MG/L)

Fig. 12

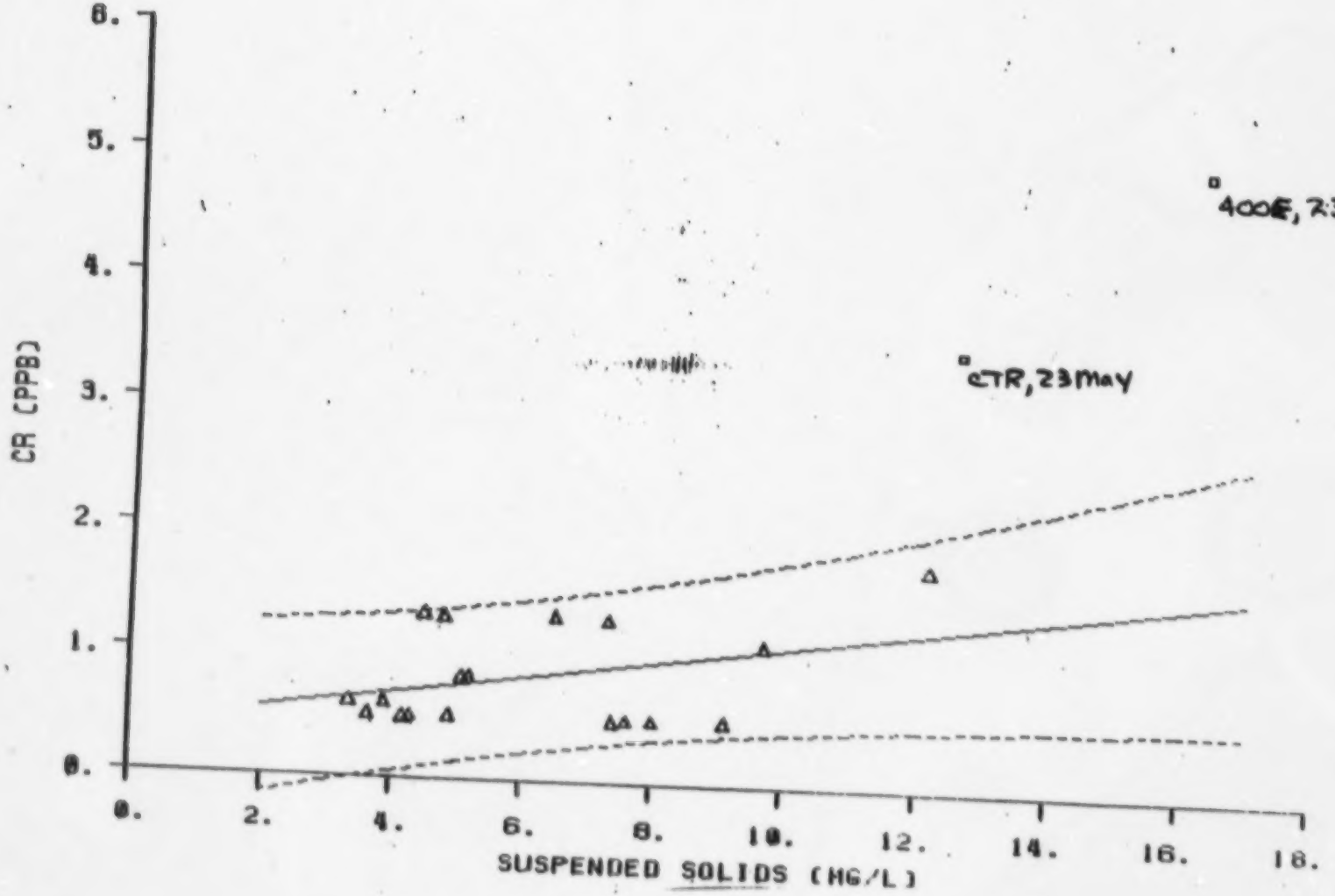

CR (PPB)
0.
1.
2.
3.
4.
5.
6.
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SUSPENDED SOLIDS (MG/L)
400E, 23 May
CTR, 23 May

Fig. 13

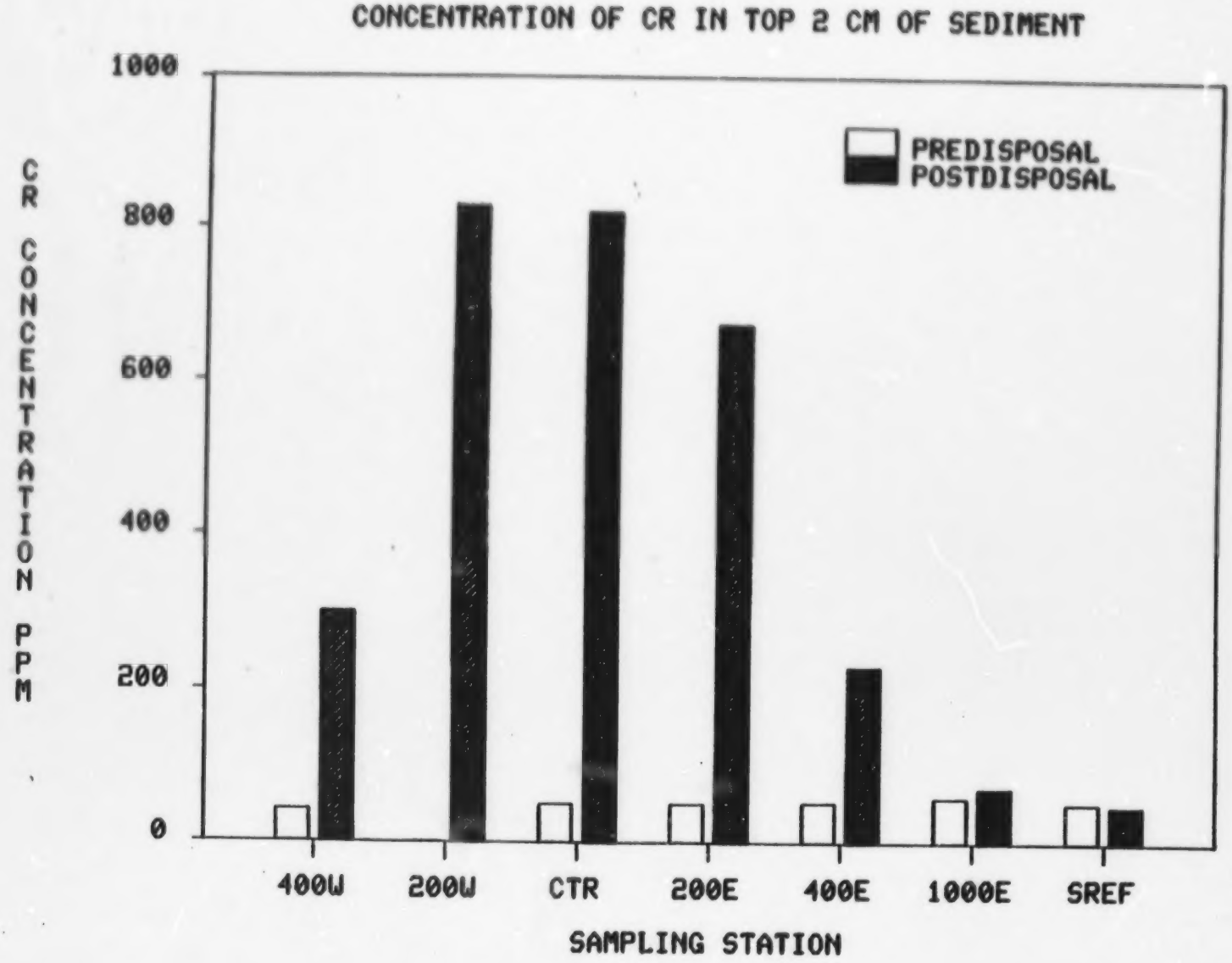

CONCENTRATION OF CR IN TOP 2 CM OF SEDIMENT
CR CONCENTRATION PPM
1000
800
600
400
200
0
PREDISPOSAL
POSTDISPOSAL
400W
200W
CTR
200E
400E
1000E
SREF
SAMPLING STATION

Fig. 14a

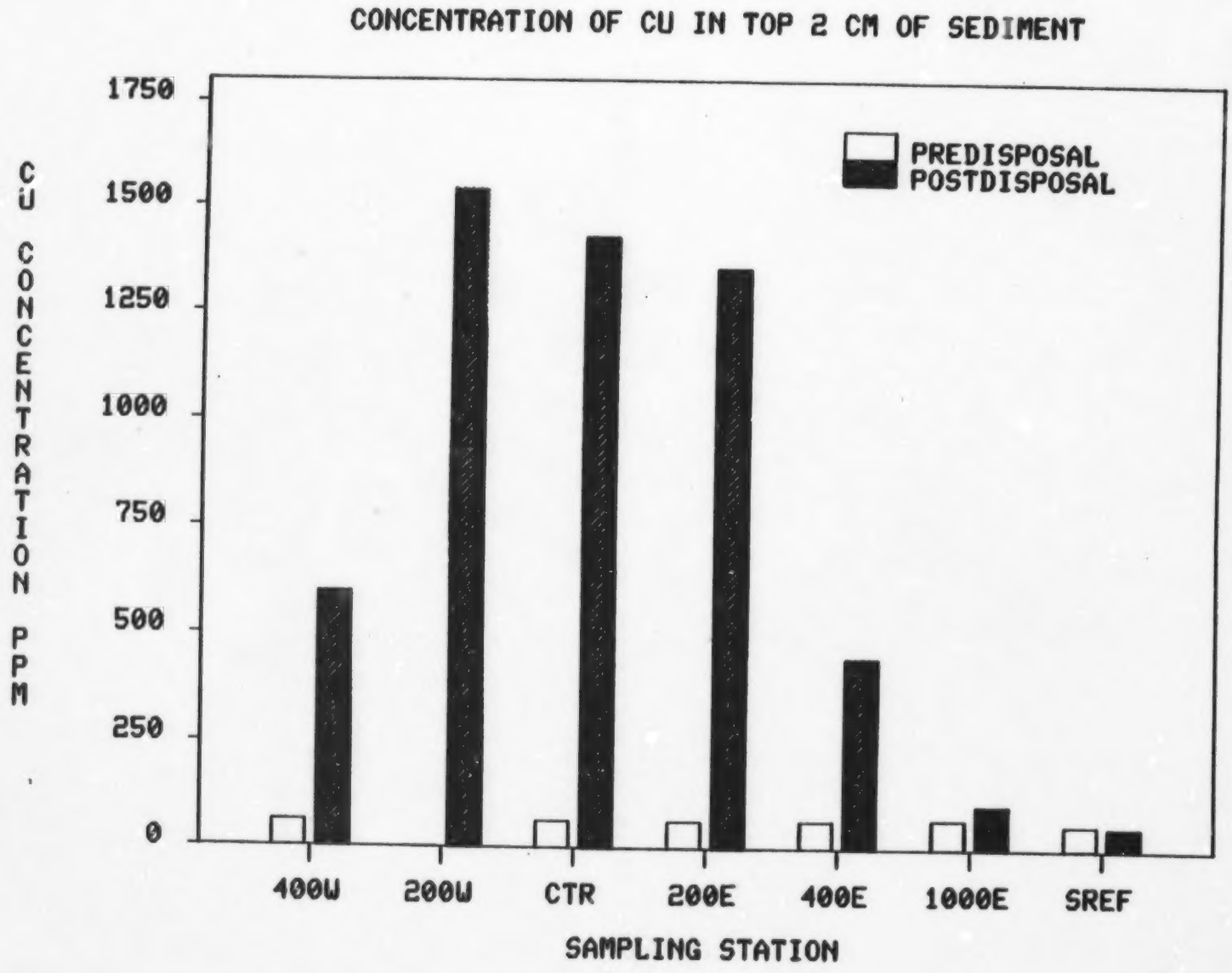

CONCENTRATION OF CU IN TOP 2 CM OF SEDIMENT
CU CONCENTRATION PPM
1750
1500
1250
1000
750
500
250
0
PREDISPOSAL
POSTDISPOSAL
400W
200W
CTR
200E
400E
1000E
SREF
SAMPLING STATION

Fig. 14b

>69

69

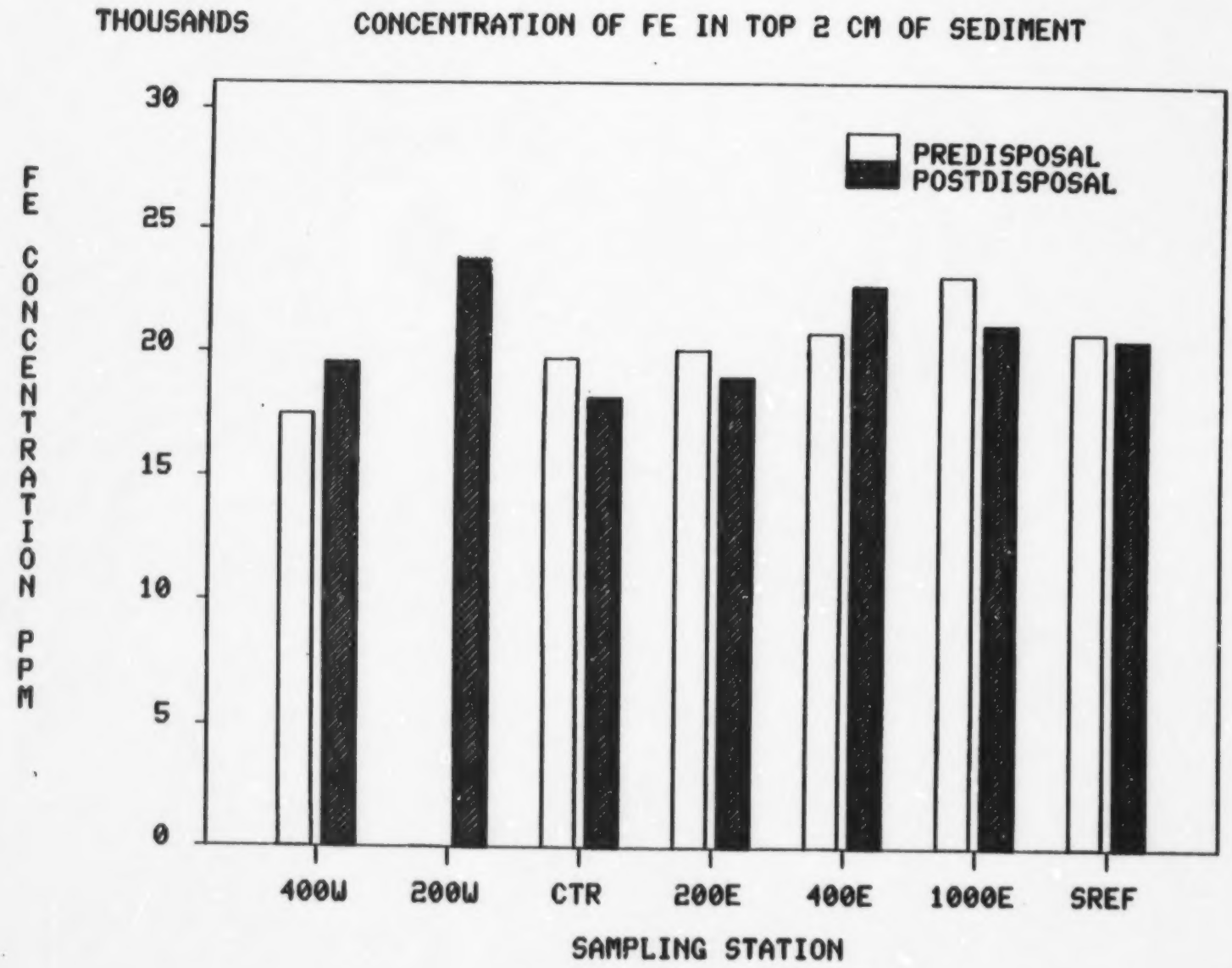

THOUSANDS
CONCENTRATION OF FE IN TOP 2 CM OF SEDIMENT
FE CONCENTRATION PPM
30
25
20
15
10
5
0
PREDISPOSAL
POSTDISPOSAL
400W
200W
CTR
200E
400E
1000E
SREF
SAMPLING STATION

Fig. 14c

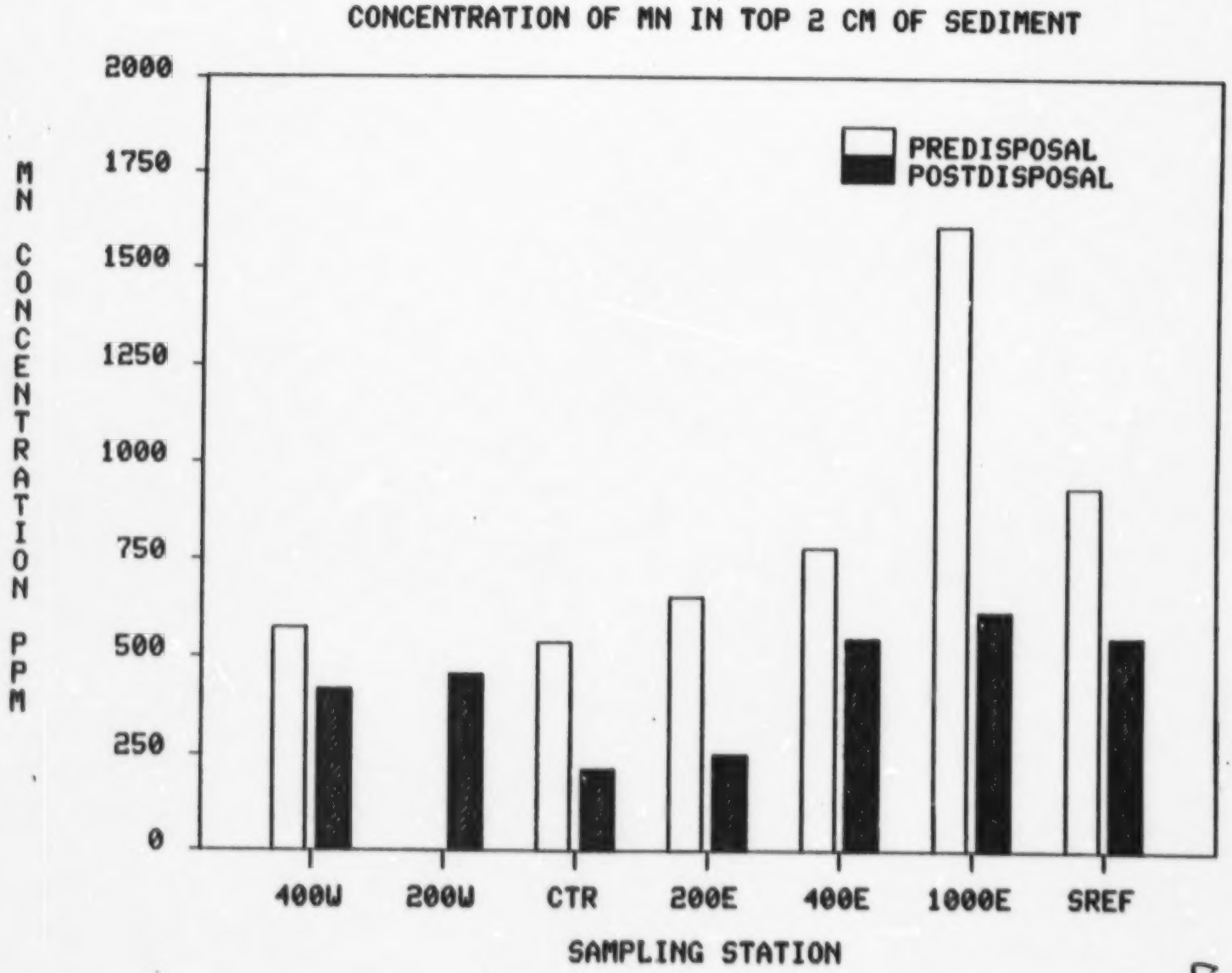

CONCENTRATION OF MN IN TOP 2 CM OF SEDIMENT
MN CONCENTRATION PPM
2000
1750
1500
1250
1000
750
500
250
0
PREDISPOSAL
POSTDISPOSAL
400W
200W
CTR
200E
400E
1000E
SREF
SAMPLING STATION

Fig. 14d

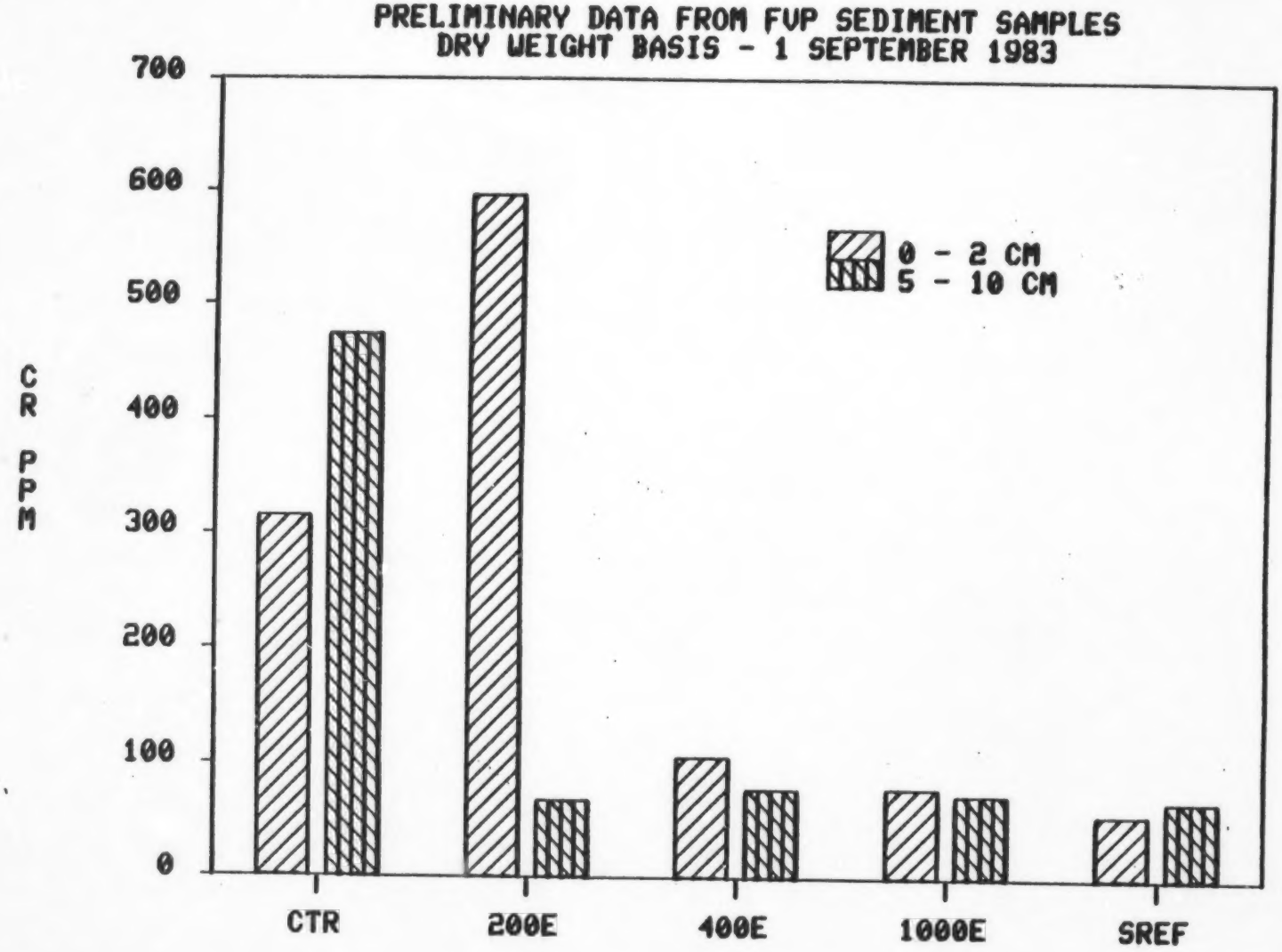

PRELIMINARY DATA FROM FVP SEDIMENT SAMPLES
DRY WEIGHT BASIS - 1 SEPTEMBER 1983
700
600
500
400
300
200
100
0
CR PPM
0 - 2 CM
5 - 10 CM
CTR
200E
400E
1000E
SREF

Fig. 15a

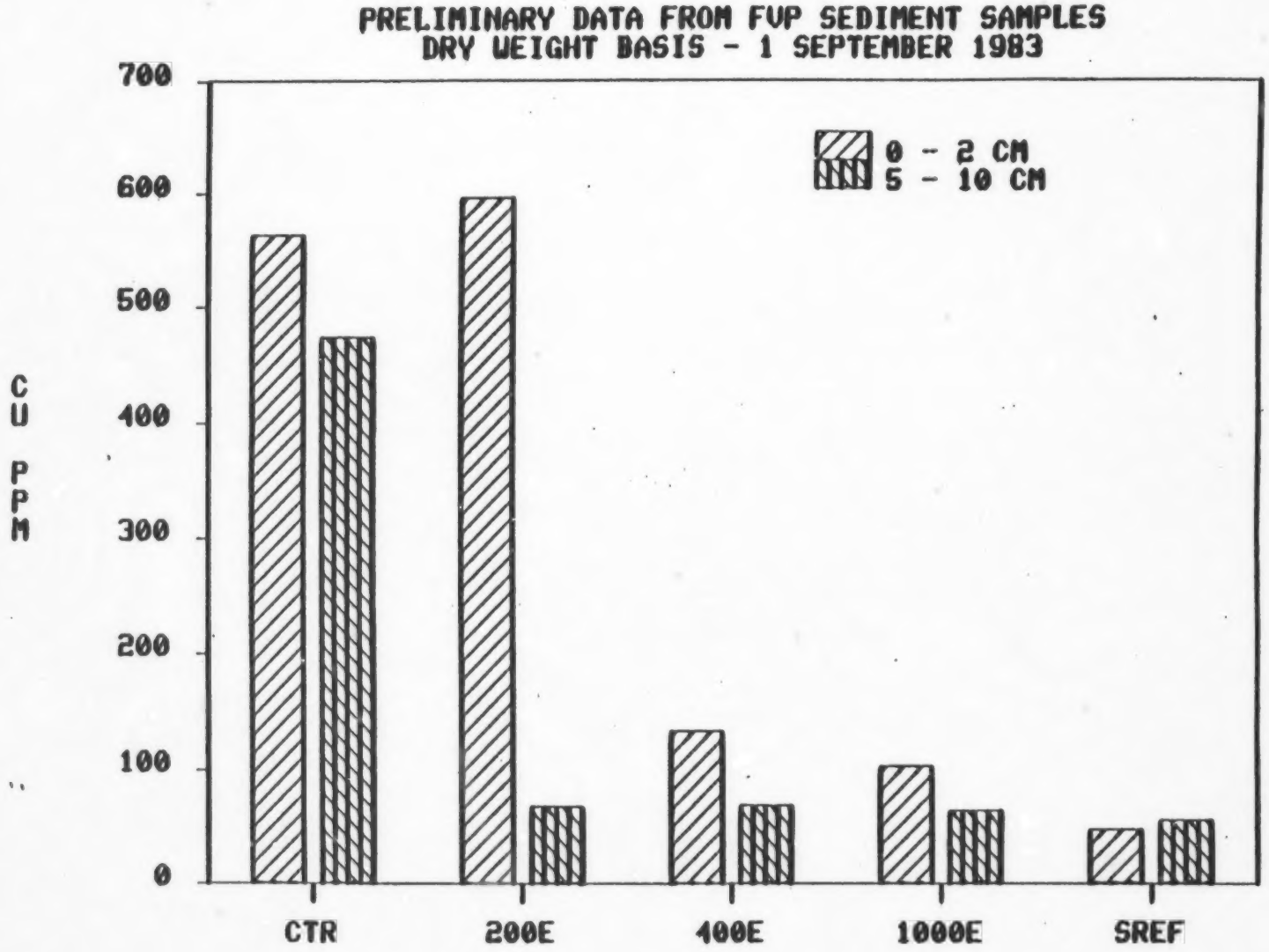

PRELIMINARY DATA FROM FVP SEDIMENT SAMPLES
DRY WEIGHT BASIS - 1 SEPTEMBER 1983
0 - 2 CM
5 - 10 CM
CU PPM
700
600
500
400
300
200
100
0
CTR
200E
400E
1000E
SREF

Fig. 15b

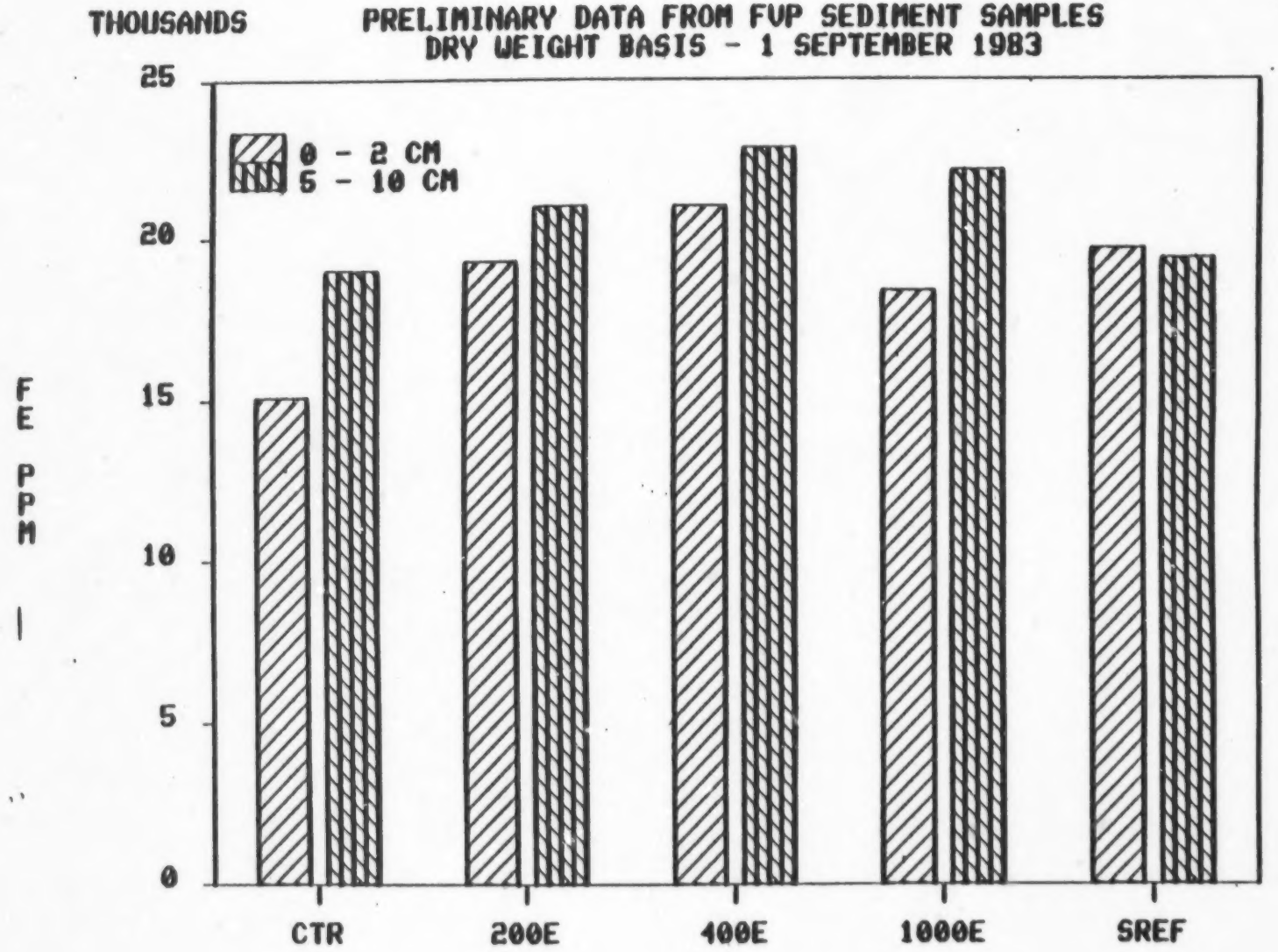

THOUSANDS
PRELIMINARY DATA FROM FVP SEDIMENT SAMPLES
DRY WEIGHT BASIS - 1 SEPTEMBER 1983
25
20
15
10
5
0
FE PPM
0 - 2 CM
5 - 10 CM
CTR
200E
400E
1000E
SREF

Fig. 15c

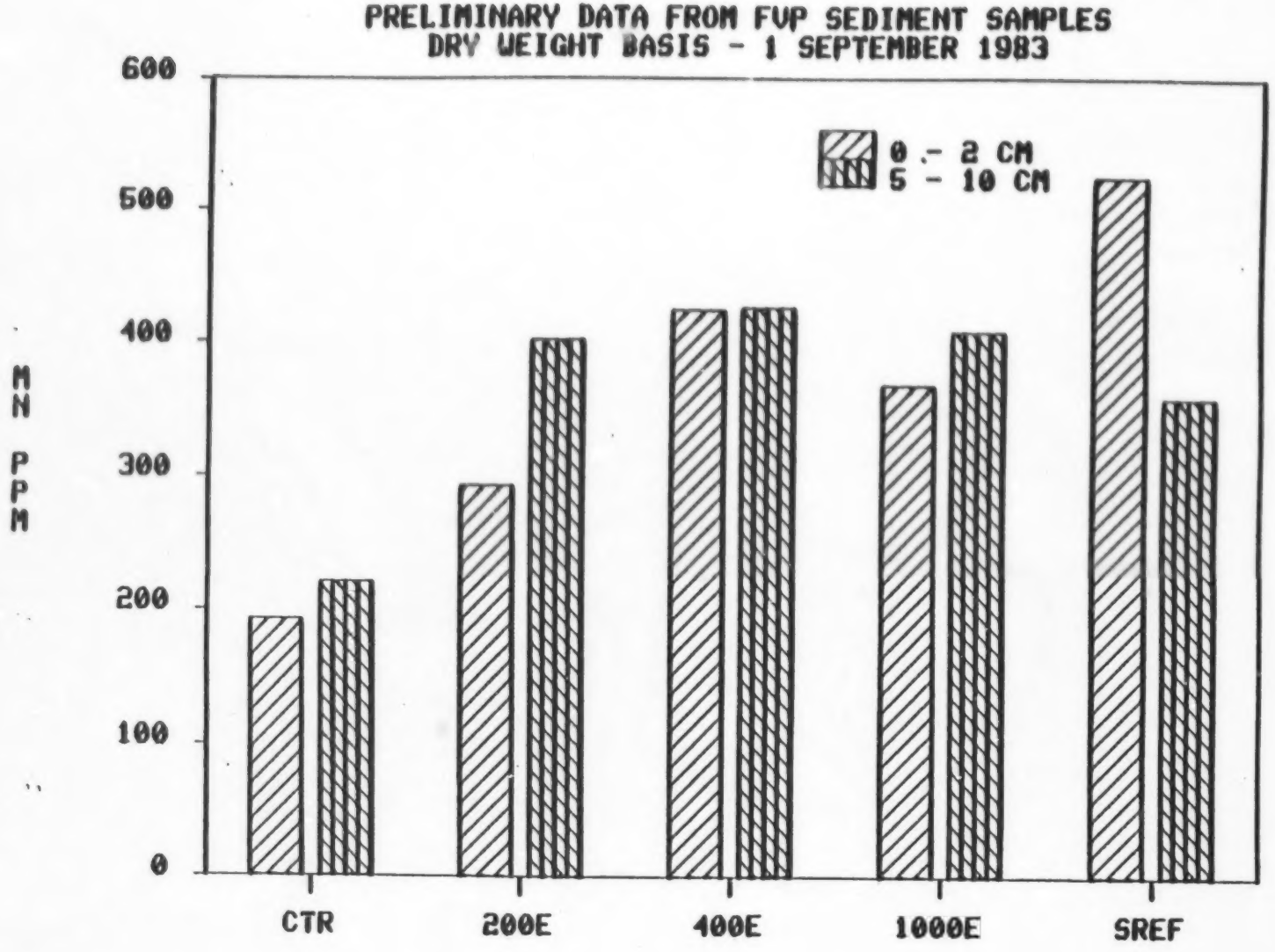

PRELIMINARY DATA FROM FVP SEDIMENT SAMPLES
DRY WEIGHT BASIS - 1 SEPTEMBER 1983
0 - 2 CM
5 - 10 CM
MN PPM
600
500
400
300
200
100
0
CTR
200E
400E
1000E
SREF

Fig. 15d

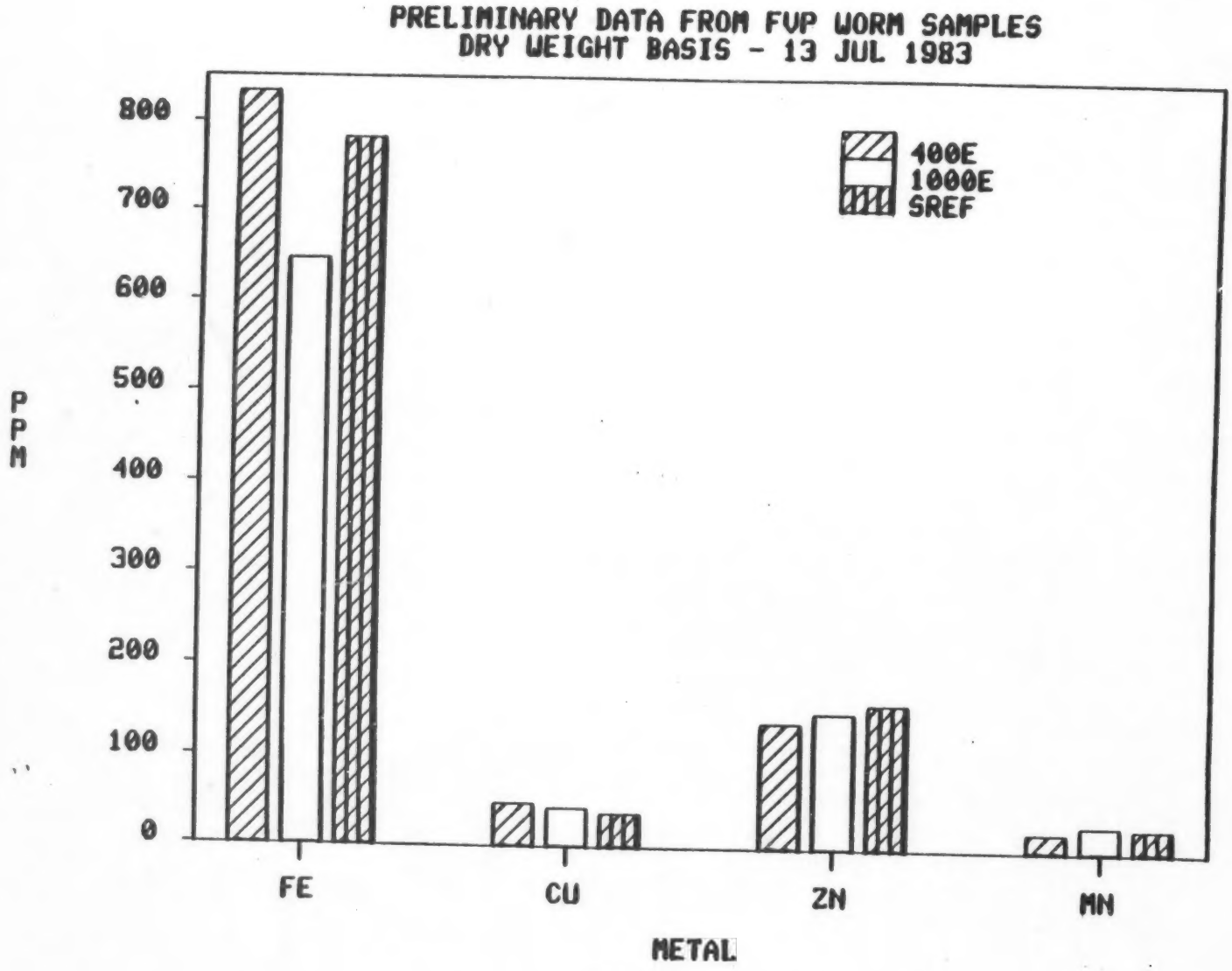

PRELIMINARY DATA FROM FVP WORM SAMPLES
DRY WEIGHT BASIS - 13 JUL 1983
800
700
600
500
400
300
200
100
0
PPM
400E
1000E
SREF
FE
CU
ZN
MN
METAL

Fig. 16a

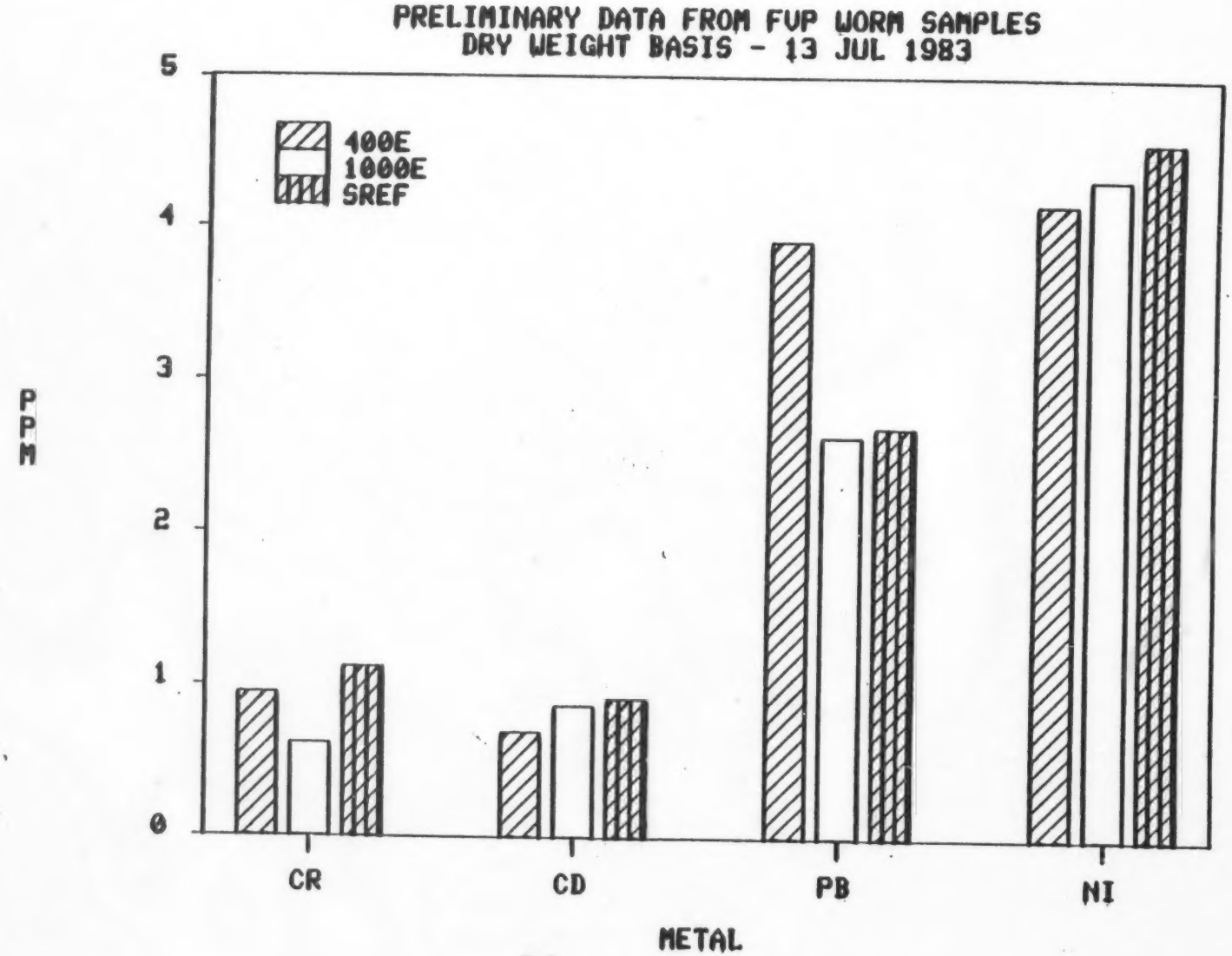

PRELIMINARY DATA FROM FVP WORM SAMPLES
DRY WEIGHT BASIS - 13 JUL 1983
400E
1000E
SREF
PPM
5
4
3
2
1
0
CR
CD
PB
NI
METAL

Fig. 16b

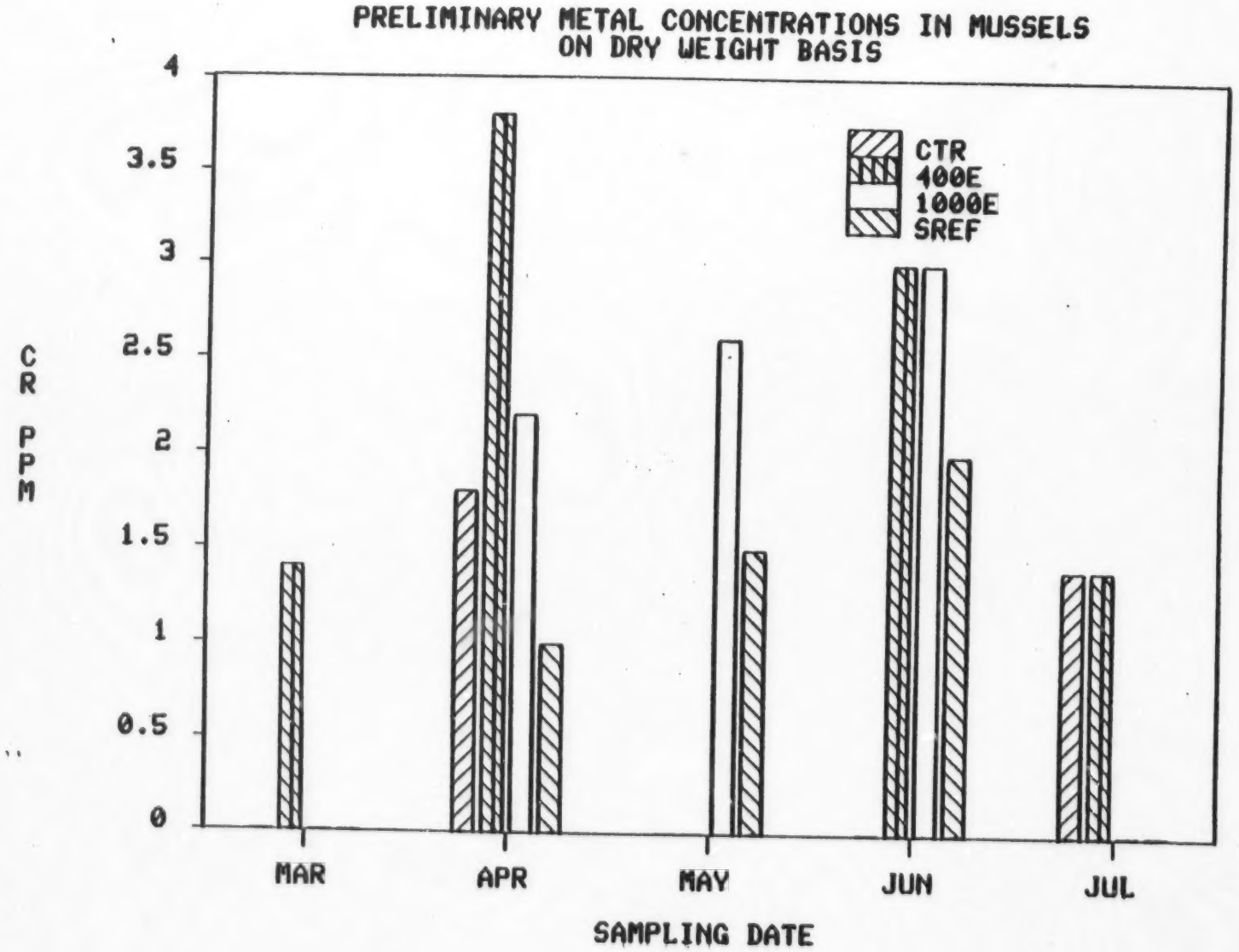

PRELIMINARY METAL CONCENTRATIONS IN MUSSELS
ON DRY WEIGHT BASIS
CR PPM
4
3.5
3
2.5
2
1.5
1
0.5
0
CTR
400E
1000E
SREF
MAR
APR
MAY
JUN
JUL
SAMPLING DATE

Fig. 17a

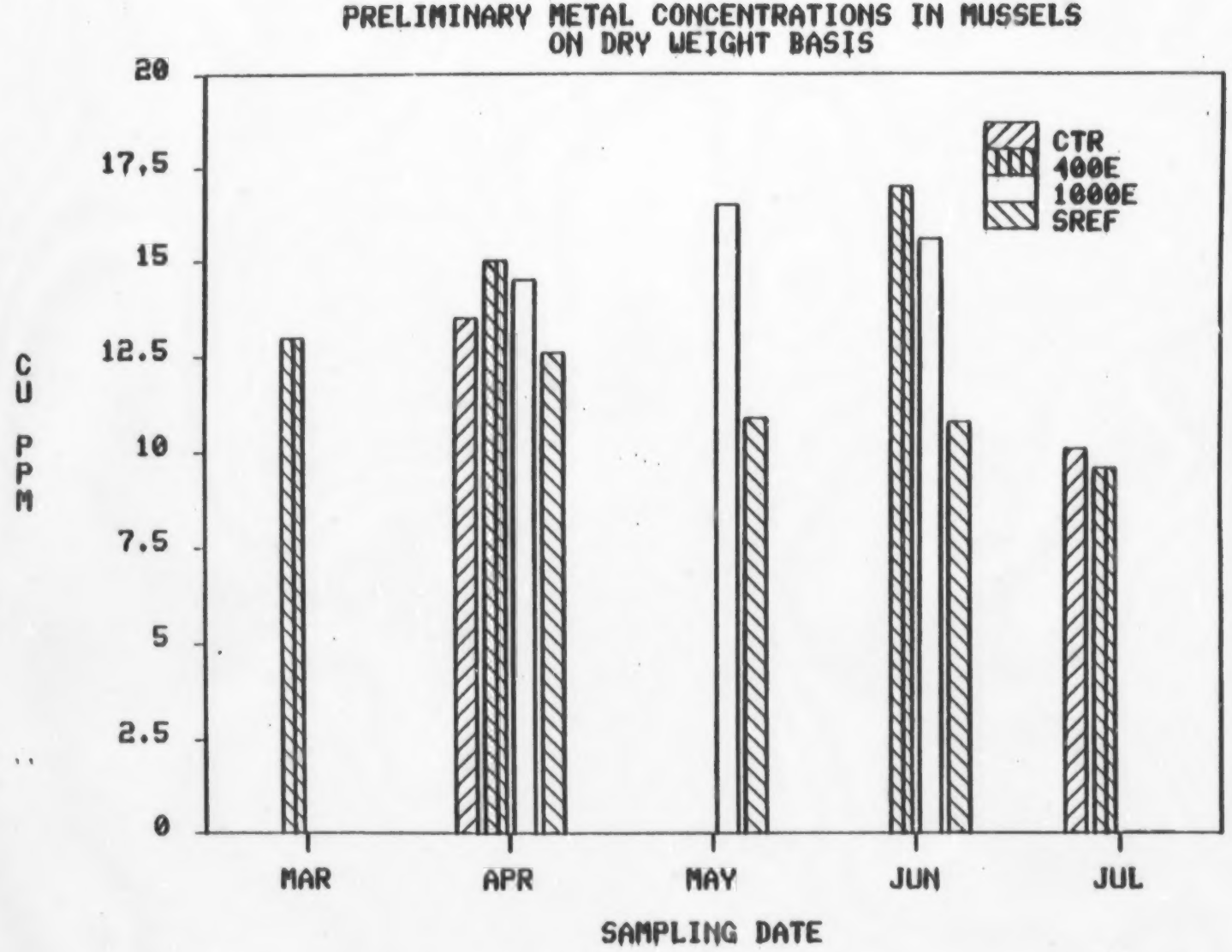

PRELIMINARY METAL CONCENTRATIONS IN MUSSELS
ON DRY WEIGHT BASIS
CU PPM
20
17.5
15
12.5
10
7.5
5
2.5
0
CTR
400E
1000E
SREF
MAR
APR
MAY
JUN
JUL
SAMPLING DATE

Fig. 17b

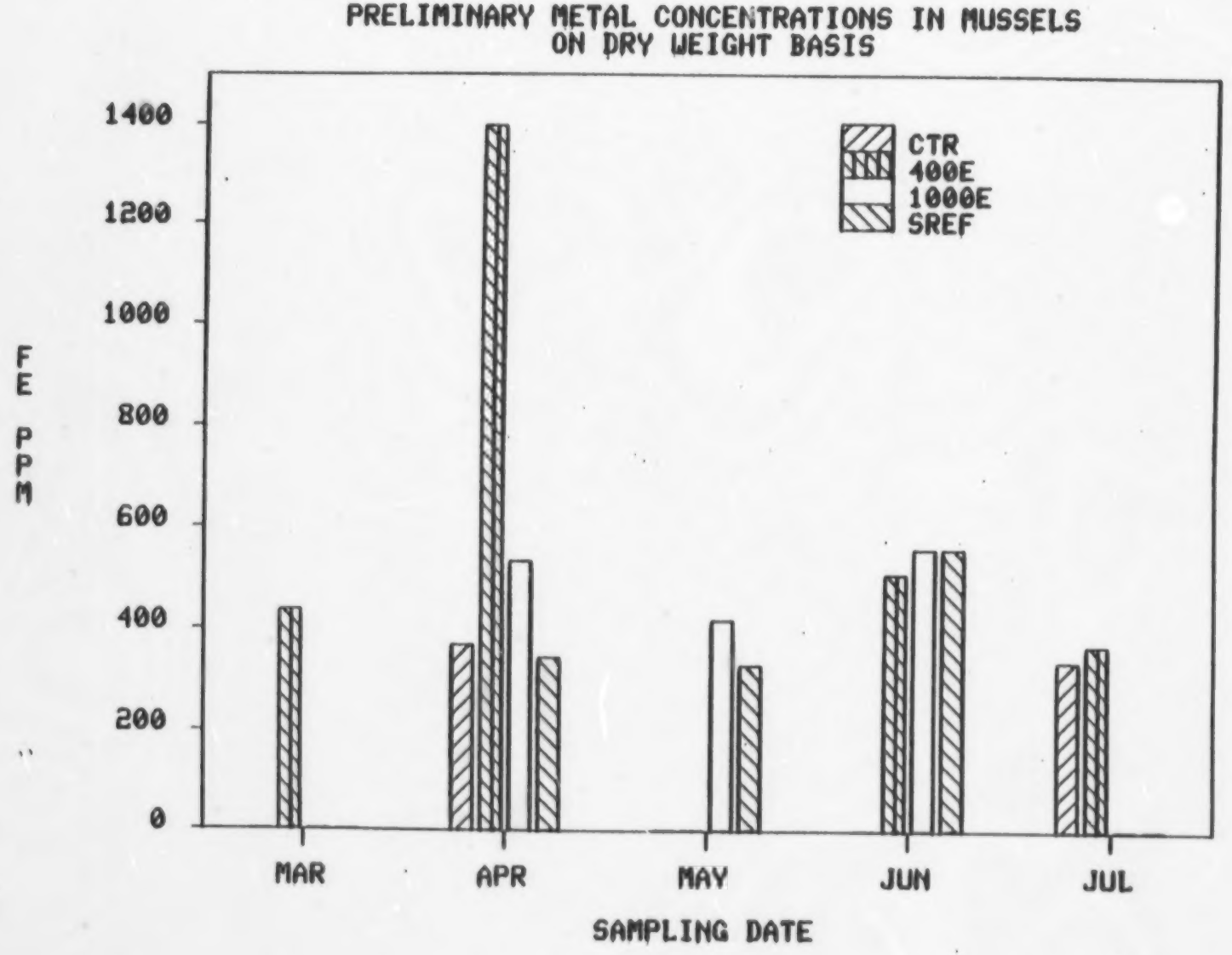

PRELIMINARY METAL CONCENTRATIONS IN MUSSELS
ON DRY WEIGHT BASIS
1400
1200
1000
800
600
400
200
0
FE PPM
CTR
400E
1000E
SREF
MAR
APR
MAY
JUN
JUL
SAMPLING DATE

Fig. 17c

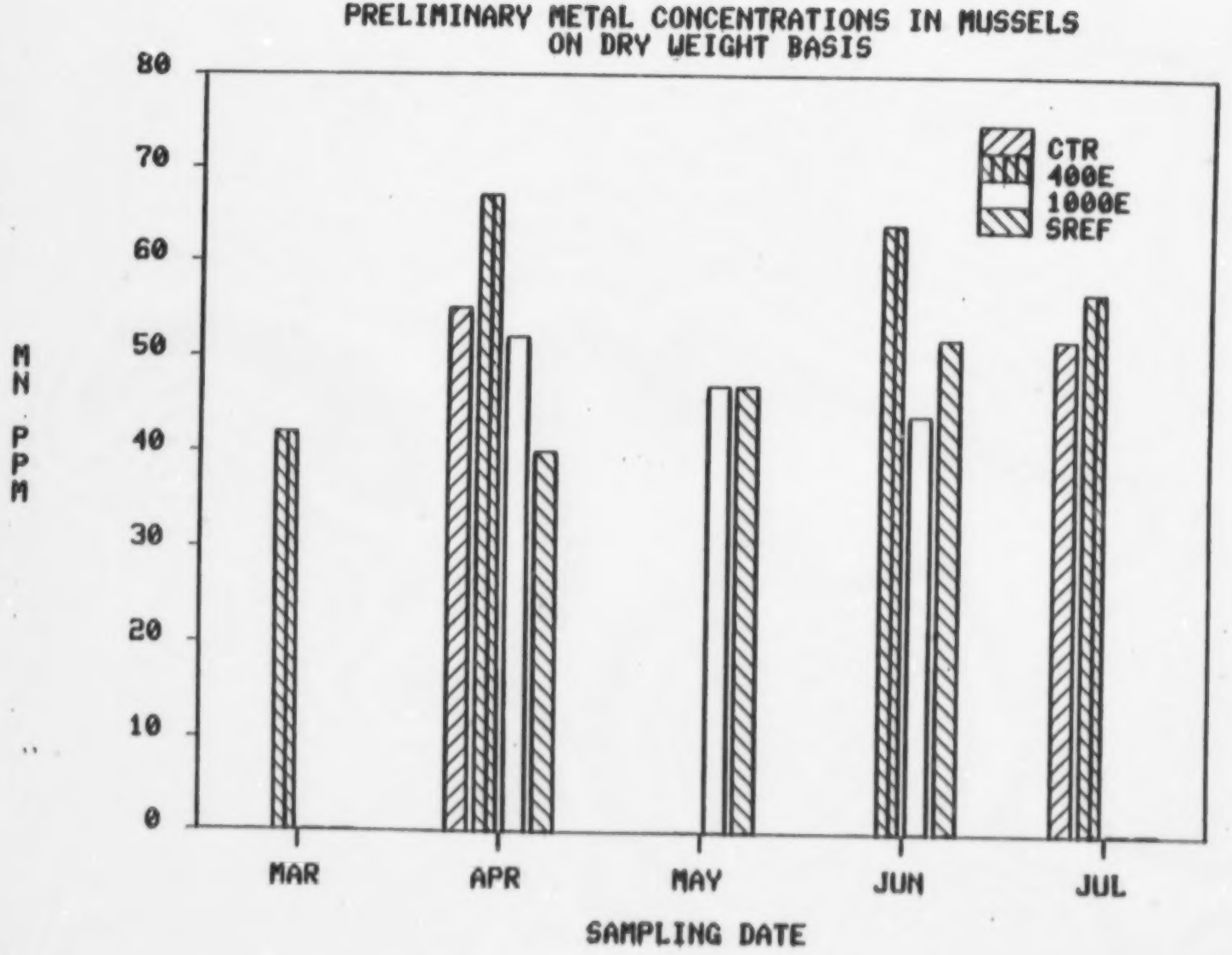

PRELIMINARY METAL CONCENTRATIONS IN MUSSELS
ON DRY WEIGHT BASIS
MN PPM
80
70
60
50
40
30
20
10
0
CTR
400E
1000E
SREF
MAR
APR
MAY
JUN
JUL
SAMPLING DATE

Fig. 17d

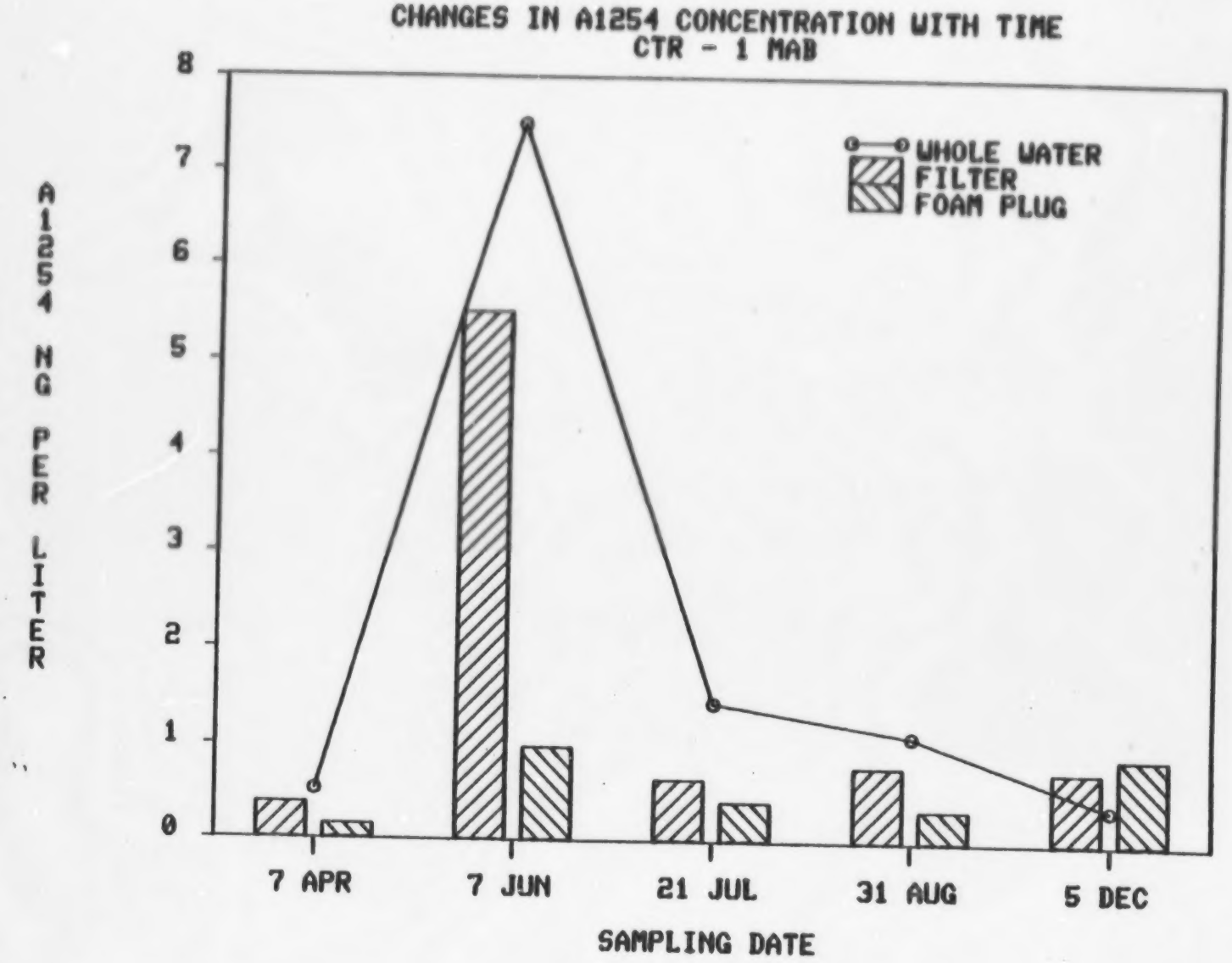

CHANGES IN A1254 CONCENTRATION WITH TIME
CTR - 1 MAB
WHOLE WATER
FILTER
FOAM PLUG
A1254 NG PER LITER
8
7
6
5
4
3
2
1
0
7 APR
7 JUN
21 JUL
31 AUG
5 DEC
SAMPLING DATE

Fig. 18a

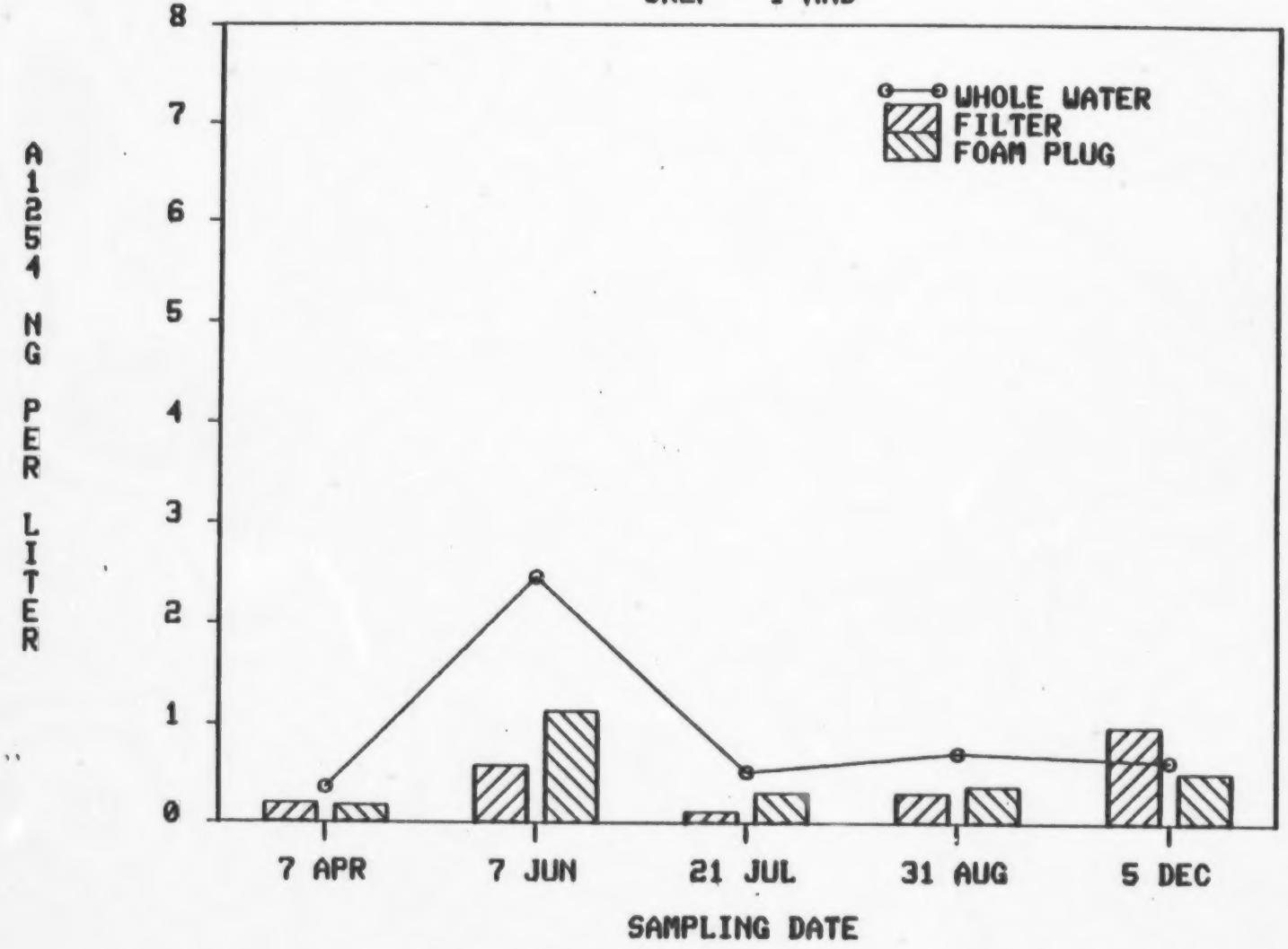

CHANGES IN A1254 CONCENTRATION WITH TIME
SREF - 1 MAB
WHOLE WATER
FILTER
FOAM PLUG
A1254 NG PER LITER
8
7
6
5
4
3
2
1
0
7 APR
7 JUN
21 JUL
31 AUG
5 DEC
SAMPLING DATE

Fig. 186

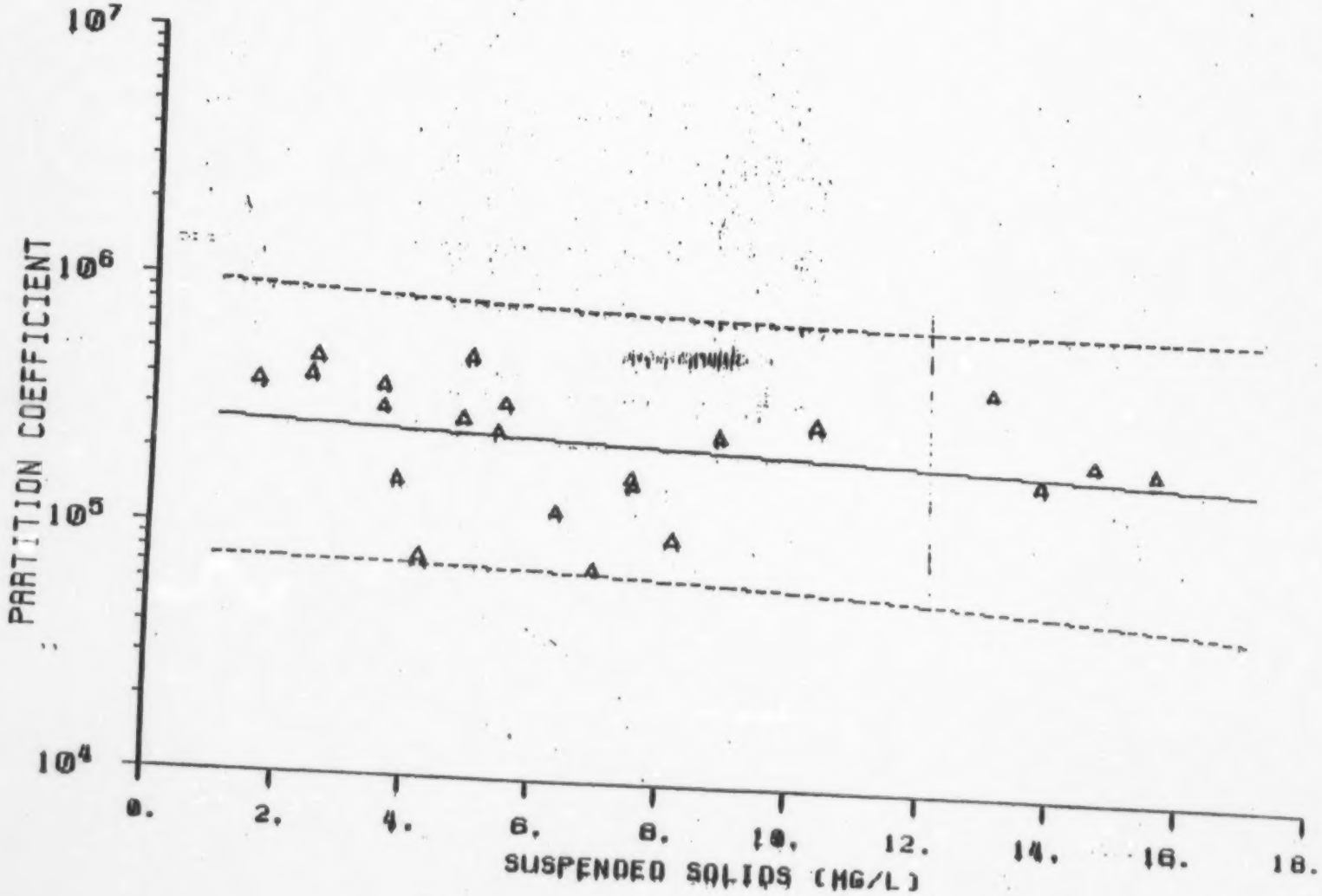

PARTITION COEFFICIENT
10^7
10^6
10^5
10^4
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SUSPENDED SOLIDS (MG/L)

Fig. 19

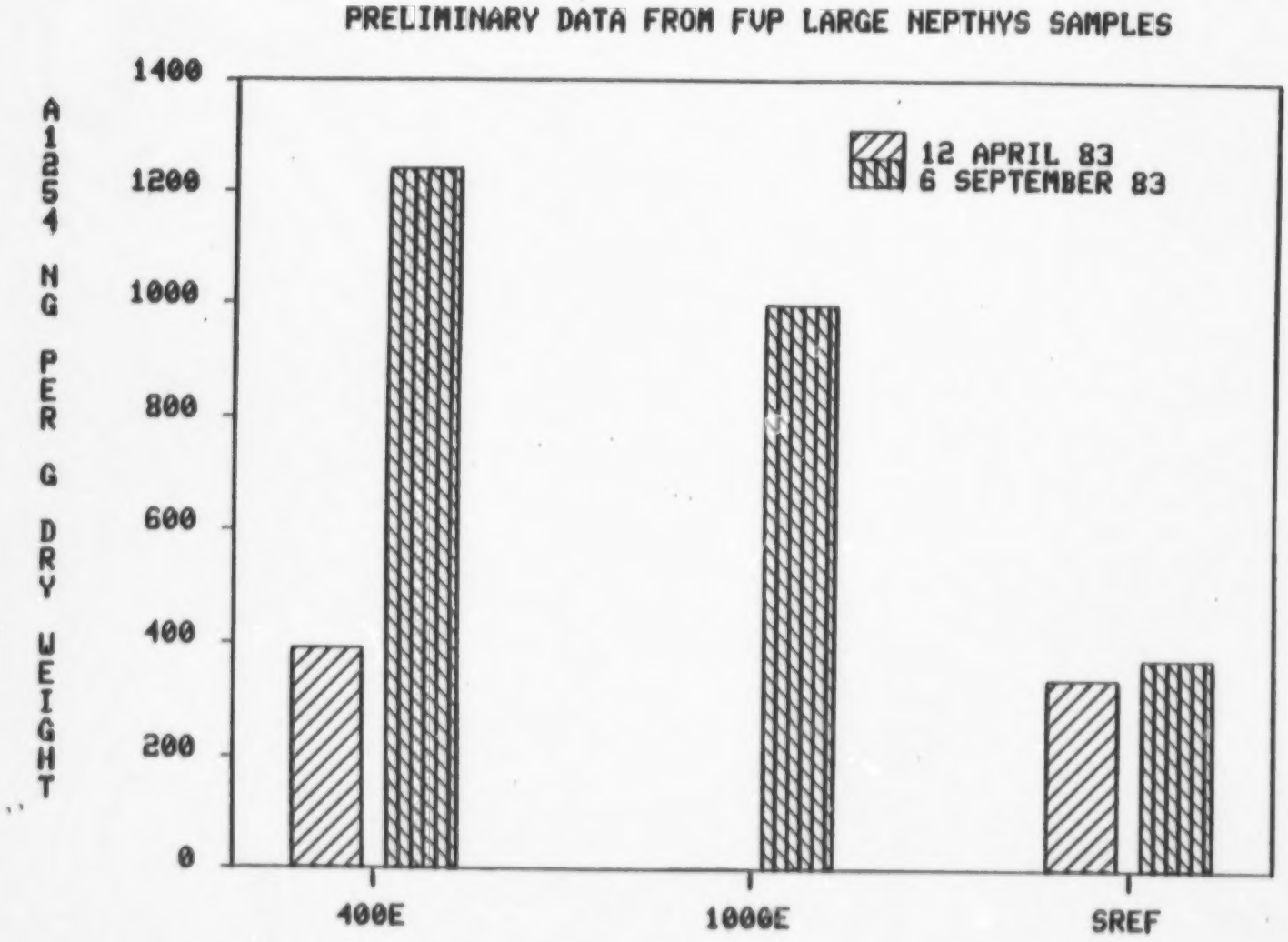

PRELIMINARY DATA FROM FVP LARGE NEPTHYS SAMPLES
A1254 NG PER G DRY WEIGHT
1400
1200
1000
800
600
400
200
0
12 APRIL 83
6 SEPTEMBER 83
400E
1000E
SREF

Fig. 20

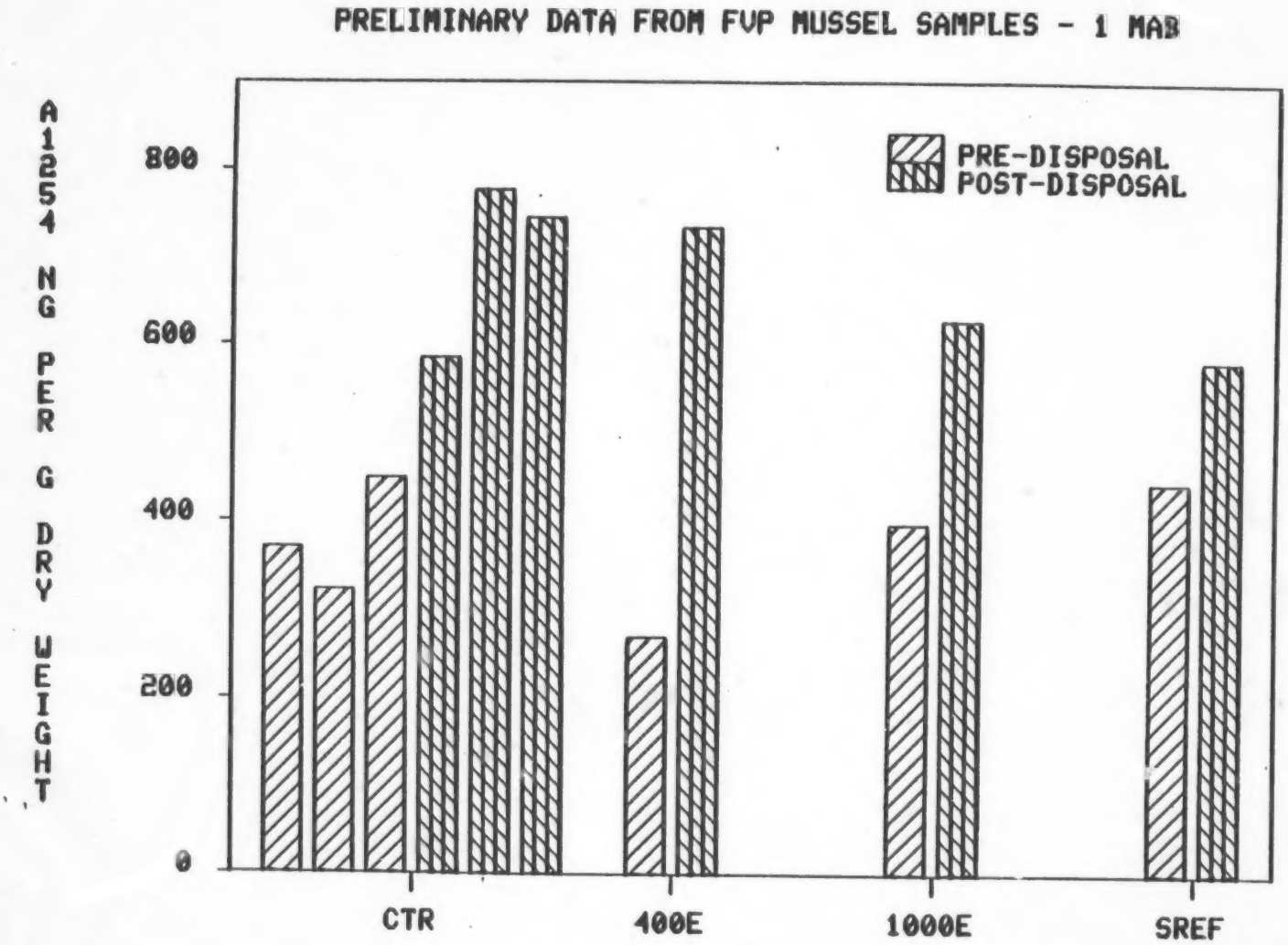

PRELIMINARY DATA FROM FVP MUSSEL SAMPLES - 1 MAB
A1254 NG PER G DRY WEIGHT
800
600
400
200
0
PRE-DISPOSAL
POST-DISPOSAL
CTR
400E
1000E
SREF

Fig. 21